GUIDELINES FOR THE DESIGN OF WATER STORAGE FACILITIES, WATER DISTRIBUTION SYSTEMS, SANITARY SEWAGE SYSTEMS AND STORM SEWERS

May 1979

Ministry of the Environment
Ontario

The Honourable
Keith C. Norton, Q.C.,
Minister

Gérard J. M. Raymond
Deputy Minister

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ACKNOWLEDGEMENTS

This design guideline has been prepared with the assistance of the consulting firm of Simcoe Engineering Limited, Pickering, Ontario. The draft guideline, prepared by the consultant, underwent an initial review by a committee including representatives from District, Metropolitan, and Regional Municipalities. The members of this committee were as follows:

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Following this initial review, revisions were made and the document underwent a final review by committees consisting of representatives from the local municipalities within the various District, Metropolitan, and Regional Municipalities. The present form of the guideline includes changes suggested by these latter committees.

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1.0 INTRODUCTION

Par 1 This edition of guidelines has been prepared as a revision to the previous issue No. 2 dated October, 1975.

Par 2 It is the intention of the Ministry that this guide be utilized in determining the size of water storage facilities to be provided in small water supply systems, requiring approval under Section 41 of the Ontario Water Resources Act. This Section basically covers all water works except those supplying non-potable water, or providing potable water to five or fewer private residences.

Par 3 The enclosed method of determining total storage requirements is, in the opinion of the Ministry, a reasonable one, but should not necessarily be construed as fulfilling the requirements (fire) of the municipality's insurance company.

Par 4 It is not the practice of the Ministry, on its own projects, to size its systems (supply, distribution or storage) to meet the requirements of high demand or high risk (fire) industries unless prior arrangements have been made with the industry for cost sharing. See Appendix A for the MOE policy on fire flow allowances for Provincially-financed projects. It is recommended that a similar procedure be followed by municipalities in similar circumstances.

Par 5 It should be stressed that the level of fire protection provided is the responsibility of the municipality in the case of the design of a municipal system and the responsibility of the individual owner in the case of the design of a private system.

Par 6 To allow the guidelines to be more simply modified in future and to permit faster reference by the users to specific paragraphs of the text, the guidelines have been broken down into numbered sections and paragraphs as shown along the left hand margin of each page.

Par 7 As a final point, it must be emphasized that this document contains design guidelines. These should not be confused with standards or regulations which must be absolutely complied with in order to obtain approval. It is not the intention of the Ministry of the Environment to stifle innovation. Whenever a designer can demonstrate that environmental and/or health concerns can be safeguarded by alternative approaches, such methods will be considered for approval.

1.1 TYPES OF WATER STORAGE FACILITIES

Par 1 In a water supply system there are many alternative methods available for the provision of water storage. Storage can be provided at the water purification

plant or in the water distribution system as follows:

Water Purification Plant	- clearwell storage
	- ground level storage
Distribution System	- elevated storage
	- ground level storage

Par 2 The type of water storage facility selected will depend on many factors such as size of service area, topography, costs, etc. It is not the intention of the guidelines to assist the designer with the selection of the most appropriate or economical type of storage. These guidelines should be used to establish the total water supply system storage requirements and used in the detailed design of the selected water storage facility.

Par 3 The top water level of the storage facility should be set to result in acceptable service pressures as outlined in the "Guidelines for the Design of Water Distribution Systems".

1.2 SIZING OF STORAGE FACILITIES

Par 1 The total water storage requirements (exclusive of storage required for the operation of the water purification plant) for a given water supply system should be established based on the method outlined in Appendix B. As noted above, the

storage can be located at the water plant site or within the distribution system and can be elevated or ground level, depending on many factors.

Par 2 The design method outlined in Appendix B assumes that the water treatment plant is capable of satisfying only the maximum day demand. If it is capable of supplying more than this, the storage requirements can be reduced accordingly.

1.3 STORAGE REQUIRED FOR THE OPERATION OF THE WATER PURIFICATION PLANT

Par 1 Some storage is required at the water purification plant site for the proper operation of the plant. This storage is in addition to the storage requirement based on the design criteria in Appendix B.

Par 2 This storage at the plant site should be calculated based on the volume of the filter backwash water required and there should be some allowance for the volume of water required when a filter is out of service during backwashing.

Par 3 The site storage can be provided in a clearwell or in a separate ground storage reservoir.

2.0 DESIGN GUIDELINES FOR STORAGE FACILITIES

2.1 GROUND STORAGE RESERVOIRS

2.1.1 Site Selection

Par 1 After the top water level of the reservoir has been set then a site should be selected which results in an economical design. Most ground level reservoirs have a water depth of approximately 6 m (20 ft.). An economical design usually results if the excavation below original ground is about one-half of the total water depth.

Par 2 When locating the reservoir relative to the existing ground, many factors should be considered such as:

- structural costs based on soils conditions and location of the ground water table;
- excavation costs based on cut and fill considerations;
- the top of the reservoir should not be less than 0.6 m (2 ft.) above the original ground surface or normal flood level of any adjacent body of water.

Par 3 Other factors which should be considered when locating a ground storage reservoir are:

- sewers, drains, standing water and similar sources of contamination must be kept at least 15 m (50 ft.) away from the reservoir

(mechanical-joint water pipe, pressure tested in place at 350 kPa (50 psi) without leakage, may be used for gravity sewers at lesser separations);

- future expansion;
- site access.

2.1.2 Number of Cells

Par 1 Wherever practical, reservoirs should be constructed with two cells for maintenance and flexibility reasons unless there is an economical constraint. Quite often two cells can readily be provided as a result of phasing requirements.

2.1.3 Protection

Par 1 Fencing, locks on access manholes and valve and vent houses should be provided. Also, care should be taken in the design to guard against trespassing, vandalism and sabotage.

Par 2 Further, when the reservoir is located on farmland, the site should be fenced to prevent farm animals from having access to the reservoir roof to avoid pollutional hazards.

Par 3 All finished water storage structures should have suitable watertight roofs and any opening should have suitable covers to prevent entrance of birds, animals, insects or excessive dust.

2.1.4 Roof and Sidewall

Par 1 The roof and sidewalls of all structures must be watertight with no openings except properly constructed vents, manholes, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow.

a) Any pipes running through the roof or sidewall of a finished water storage structure must be welded or properly gasketed in metal tanks, or should be connected to standard wall castings which were poured in place during the forming of the concrete structure; these wall castings should have flanges imbedded in the concrete.
b) Openings in a storage structure roof or top, designed to accommodate control apparatus or pump columns, shall be curbed and sleeved with proper additional shielding to prevent the access of surface or slop water to the structure.
c) Where possible, valves and controls should be located outside the storage structure so that valve stems and similar projections will not pass through the roof or top of the reservoir.

2.1.5 Drainage for Roof or Cover

Par 1 The roof or cover of the storage structure should be well drained, but down-spout pipes shall not

enter or pass through the reservoir; parapets, or similar construction which would tend to hold water on the roof, will not be approved.

2.1.6 Access

Par 1 Finished water storage structures shall be designed with reasonably convenient access (i.e. minimum 900 mm (36 in.) opening) to the interior for cleaning and maintenance.

Par 2 Manholes above waterline:

a) Should be framed at least 100 mm (4 in.), and preferably 150 mm (6 in.) above the surface of the roof at the opening; on ground level structures, manholes should be elevated 450 mm (18 in.) above the top or covering sod;
b) Should be fitted with a solid watertight cover which overlaps the framed opening and extends down around the frame at least 50 mm (2 in.);
c) Should be hinged at one side using non-removable hinges;
d) Should have a locking device.

2.1.7 Vents

Par 1 Finished water storage structures shall be vented by special vent structures. Open construction between the sidewall and roof is not permissible.

These vents:

a) Should prevent the entrance of surface water;

b) Should exclude birds and animals;

c) Should exclude insects and dust, as much as this function can be made compatible with effective venting; for elevated tanks and standpipes, four-mesh non-corrodible screen may be used;

d) Shall, on ground level structures, terminate in an inverted 'U' construction, the opening of which is 600 to 900 mm (24 to 36 in.) above the roof or sod and is covered with twenty-four mesh non-corrodible screen cloth.

2.1.8 Drains

Par 1 It is recommended that no drain on a water storage structure be directly connected to a sewer or storm drain.

2.1.9 Overflow

Par 1 It is recommended that no overflow be directly connected to a sewer or storm drain.

Par 2 The overflow of a ground level structure shall be high enough above original or graded ground surface to prevent the entrance of surface water.

2.1.10 Circulation

Par 1 Positive circulation of the water in the reservoir should be provided wherever possible, to avoid depletion of the chlorine residual. This can be accomplished by strategic location of the inlet and outlet piping. Where there is more than one cell then the inlet should be to one cell and the outlet from another. This will ensure that there is good circulation from one cell to another. There should, of course, be the flexibility for operating with one cell out of service.

2.1.11 Safety

Par 1 The safety of the employees must be considered in the design of the storage structure. As a minimum, such matters shall conform to the Ministry of Labour requirements and other pertinent laws and regulations of the Province.

a) Ladders, ladder guards, balcony railings, and safe location of entrance hatches shall be provided where applicable.

b) Elevated tanks with riser pipes over 200 mm (8 in.) in diameter shall have protected bars over the riser openings inside the tank.

2.1.12 Freezing

Par 1 All finished water storage structures and their

appurtenances, especially overflows, and vents, shall be designed to prevent freezing which will interfere with proper functioning.

2.1.13 Internal Catwalk

Par 1 Every catwalk over finished water in a storage structure shall have a solid floor with raised edges so designed that shoe scrapings and dirt will not fall into the water.

2.1.14 Grading

Par 1 The area surrounding a ground-level structure should be graded in a manner that will prevent surface water from standing within 15 m (50 ft.) of the structure. Side slopes should have a grade no steeper than 3:1 for grass cutting purposes.

2.1.15 Painting and/or Cathodic Protection

Par 1 Proper protection should be given to metal surfaces by paints, varnishes and cathodic protection systems, etc.

2.2 SPECIAL CONSIDERATIONS FOR CLEARWELL STORAGE AT WATER PLANTS

2.2.1 Adjacent Compartments and Pipes Through Clearwells

Par 1 Potable water should not be stored or conveyed in a compartment adjacent to non-potable water when the

two compartments are separated by a single wall.

Par 2 Pipes carrying non-potable water should not be installed through potable water retaining structures.

Par 3 Deviations from these requirements will only be permitted on a case by case basis, if the designer is able to show that compliance with the requirement is significantly uneconomical or physically impractical and that alternate design features provide acceptable and/or equivalent levels of protection against contamination.

2.2.2 Basins and Wet-wells

Par 1 Receiving basins and pump wet-wells for finished water shall be designed as finished water storage structures.

Par 2 When finished water storage is used to provide proper contact time for chlorine, special attention must be given to size and baffling.

2.3 ELEVATED STORAGE FACILITIES

2.3.1 Pressure Variation

Par 1 The maximum variation between high and low levels in storage structures which float on a distribution system should be such that the pressures in the distribution system do not go above 690 kPa

(100 psi) nor below 275 kPa (40 psi) under normal demand periods. Pressures as low as 140 kPa (20 psi) may be acceptable when fire demands are experienced in conjunction with maximum day consumption rates.

2.3.2 Drainage

Par 1 Systems which incorporate storage structures which float on the distribution system should have the structures so designed that the distribution system pressures may be maintained when the reservoir is drained for cleaning or maintenance. The drains should discharge to the ground surface and it is recommended that no direct connection to a sewer or a storm drain be provided.

2.3.3 Overflows

Par 1 Overflow pipes should be designed where practical to discharge the peak supply rate to the reservoir. Where this is not practical, lower capacity overflows may be used, provided it can be shown that other design considerations alleviate the concerns with limited overflow capacity.

Par 2 The overflow pipe of an elevated storage tank should be brought down near the ground surface and discharged near a drainage outlet structure or a splash plate. It is recommended that no overflow be connected directly to a sanitary sewer or

storm drain.

2.3.4 Freezing

Par 1 Elevated tank structures and standpipes should be designed to prevent the occurrence of problems due to freezing. This can be accomplished by insulation, internal heating via heat tracing cables or hot water recirculation, and/or by a schedule of tank level fluctuations, etc.

2.3.5 Controls

Par 1 Adequate controls shall be provided to maintain levels in distribution system storage structures.

a) Telemetering equipment should be used when pressure type controls are employed and any appreciable head loss occurs in the distribution system between the source and the storage structure.

b) Altitude valves should be installed on elevated storage when more than one tank is required within a single supply pressure zone.

c) Overflow and low-level warnings or alarms should be located at places in the community where they will be under responsible surveillance, preferably on a 24-hour basis.

d) In general, it is the preference of operators that the high lift pumps in a system be run

on an on-off cycle with the signal being actuated by a predetermined drop in the storage tank, (i.e. elevated tank or standpipe).

Par 2 This mode of operation is felt to be the simplest and will reduce the possibility of stagnant water or freezing in the storage tank.

2.3.6 Design and Protective Coating of Steel Elevated Tanks

Par 1 The designer should refer to the latest revision of AWWA Standards D100, D101 and D102 for standards covering the design and protective coating for steel elevated tanks.

APPENDIX A

MOE Requirements For Water Storage Facilities On Provincially Funded Programs

Par 1 In principal the sizing of water storage facilities on Provincially funded projects will follow the procedure outlined in Appendix B. The primary difference will be in the fire storage allowance which will be determined in accordance with the values contained in Table 2 of Appendix B. That is, estimated costs, subsidy levels, etc. will be based upon the Total Storage Requirement calculated from Appendix B.

a) Should a municipality request that their water supply, distribution and storage facility meet the requirements of the insurance industry (I.A.O. - P.F.P.S.S.) a detailed cost comparison of the MOE sizing versus the insurance industry requirement must be undertaken. Any "oversizing" costs associated with meeting the insurance industry requirements will not be considered as eligible for Provincial subsidy and will be borne entirely by the municipality.

b) On Provincially funded projects no allowance should be made to meet the requirements of high demand or high risk (fire) industrial or commercial enterprises unless prior arrangements have

been made with the interested parties for cost sharing.

c) When determining the flow allowance for industrial or commercial areas, the area occupied by the industrial-commercial complex should be considered at a population density equal to the surrounding (abutting) residential lands.

d) Since fire protection is a municipal responsibility it is quite feasible that a municipality may elect to forego fire protection and any allowance for same. Should this situation arise on a Provincially funded project, the Ministry will accept the municipality's decision providing the decision is in the form of a Council Resolution dated after an advertised public meeting called specifically for the purpose of discussing fire protection, etc.

e) Alternative materials for construction (i.e. steel, reinforced concrete and prestressed concrete) shall be specified in the tender document and prices obtained for such alternatives, regardless of the eventual choice by the Municipality.

APPENDIX B

Design Criteria

for

Sizing Water Storage Facilities

TOTAL STORAGE REQUIREMENT = A + B + C

Where A = Fire Storage

B = Equalization Storage

(25 percent of Projected Maximum Day Demand)

C = Emergency Storage

(25 percent of "A" + "B")

Par 1 The above equation is for the calculation of the storage requirement for a system where the water treatment plant is capable of satisfying only the maximum day demand. For situations where the water treatment plant can supply more, the above storage requirements can be reduced accordingly.

Par 2 The maximum day demand referred to in the foregoing equation should be calculated using the factors in the following Table 1, unless there is existing flow data available to support a different factor. Where existing data is available, the required storage should be calculated on the basis or a careful evaluation of the flow characteristics within the system.

TABLE 1

POPULATION RANGE	MAXIMUM DAY FACTOR	PEAK RATE FACTOR (PEAK HOUR)
0 - 500	3.00	4.50
501 - 1 000	2.75	4.13
1 001 - 2 000	2.50	3.75
2 001 - 3 000	2.25	3.38
3 001 - 10 000	2.00	3.00
10 001 - 25 000	1.90	2.85
25 001 - 50 000	1.80	2.70
50 001 - 75 000	1.75	2.62
75 001 - 150 000	1.65	2.48
greater than 150 000	1.50	2.25

MAXIMUM DAY DEMAND =

Average Day Demand x Maximum Day Factor

TABLE 2

FIRE FLOW REQUIREMENTS

POPULATION	SUGGESTED FIRE FLOW		DURATION (hours)
	L/s	gpm	
under 1 000	38	500	2
1 000	64	840	2
1 500	79	1 050	2
2 000	95	1 250	2
3 000	110	1 450	2
4 000	125	1 650	2
5 000	144	1 900	2
6 000	159	2 100	3
10 000	189	2 500	3
13 000	220	2 900	3
17 000	250	3 300	4
27 000	318	4 200	5
33 000	348	4 600	5
40 000	378	5 000	6

Par 3 When determining the fire flow allowance for commercial or industrial areas, it is recommended that the area occupied by the commercial/industrial complex be considered at an equivalent population

density to the surrounding residential lands.

Par 4 NOTE: When an entirely new water supply and distribution system is being designed this guide should be used in conjunction with Guidelines for the Design of Water Distribution Systems.

APPENDIX C

Bibliography

1. AWWA Standards, American Water Works Association, 6666 West Quincy Avenue, Denver, Colorado, U.S.A. 80235

2. "Water Supply for Public Fire Protection - A Guide to Recommended Practice", (1977), Public Fire Protection Survey Services, Insurers' Advisory Organization, 180 Dundas Street West, Toronto, Ontario. M5G 1Z9

INTERIM

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1.0 INTRODUCTION

Par 1 These design guidelines have been prepared to outline the Ministry's current preferences with regard to the design of storm sewer systems. Due to the fact that the extension of combined sewer systems is discouraged by the Ministry, no attempt has been made to cover such systems in this document. These guidelines are interim in nature, since it is anticipated that policy statements will be made during 1979 that will change the approach to storm management in the Province of Ontario. New design guidelines will be issued following this policy statement.

Par 2 The guidelines covered in this document represent minimum acceptable levels of servicing that would enable the works to receive approval under the Ontario Water Resources Act. It should be noted that other approval authorities, such as the municipalities in which the works will be constructed, may have servicing standards that exceed the requirements of these guidelines. The designer should therefore ensure that he is aware of the requirements of all other approving authorities prior to submitting designs for approval.

Par 3 Although some aspects of the guidelines relate only to municipal services, the guidelines are meant to

apply where applicable to other storm sewer systems serving developments such as mobile home parks, condominiums, etc. which also require Ministry of the Environment approval under the Ontario Water Resources Act.

Par 4 Within certain watersheds of Ontario, storm water treatment is required. The designer should, before initiating a design, contact the Technical Support Section of the Ministry's Regional Office to determine if the watershed has any particular storm water treatment requirements. These guidelines have not attempted to deal with storm water treatment.

Par 5 To allow the guidelines to be more simply modified in future and to permit faster reference by the users to specific paragraphs of the text, the guidelines have been broken down into numbered sections and paragraphs as shown along the left hand margin of each page.

Par 6 As a final point, it must be emphasized that this document contains <u>design guidelines</u>. These should not be confused with standards or regulations which must be absolutely complied with, in order to obtain approval. It is not the intention of the Ministry to stifle innovation. Whenever a designer can demonstrate that environmental and public

health conditions can be safeguarded and property protected from flooding damage by alternative approaches, such methods will be considered for approval.

2.0 DESIGN FLOWS

2.1 RUNOFF COMPUTATION

Par 1 The amount of runoff from an area can generally be calculated using the Rational Formula:

$$Q = 2.78\ AIR$$

Where Q = Peak flow in L/s

A = Area in hectares

I = Average rainfall intensity in millimetres per hour for a duration equal to the time of concentration for a particular storm frequency

R = Runoff coefficient

Par 2 Calculations based on a hydrologic simulation model will also be acceptable. In fact, with systems serving large areas, or involving treatment and/or storage systems, the use of such a system may be necessary.

Par 3 The remainder of this section will deal only with the Rational Method.

2.2 DRAINAGE AREA

Par 1 The drainage area to be used in the design of a storm sewer system should include all those areas which will reasonably or naturally drain to the system.

Par 2 The area term in the Rational Formula represents the total area tributary to the point on the storm sewer system under consideration.

2.3 RAINFALL INTENSITY

Par 1 The rainfall intensity for a particular storm frequency and time of concentration should be determined from intensity - duration - frequency curves applicable for the municipality in which the system is to be constructed.

Par 2 For a discussion of rainfall intensity curves, reference should be made to the Manual of Practice on Urban Drainage and the Municipal Works Design Manual.

2.4 DESIGN STORM FREQUENCY

Par 1 The storm frequency to be used in the design of storm water conveyance systems will vary depending upon the nature of the area being served, the value of the property being protected and the consequences of more intense storms being experienced.

Par 2 The Ministry recommends that the major-minor drainage system approach should be used for all future development. By this approach, the minor, or piped storm conveyance system, provides at least the protection necessary to reduce the inconvenience of storm water ponding to an acceptable level within

the service area. The major system, or combination of piped systems, channels, roadways and overland flow routes, provides the protection necessary to convey the runoff from at least a 25-year storm without causing damage to private property. See Chapter 4 of the Manual of Practice on Urban Drainage for a discussion of the major-minor drainage system concepts.

Par 3 When this major-minor approach is used, the level of protection provided by the minor system, or storm sewers, is no longer so important. Failure of the piped system to handle a more intense rainfall than that for which it was designed should not result in private property damage due to surface runoff. Provided that facilities such as foundation drains are not permitted to be connected to the piped system, by gravity, property damage due to storm sewer surcharging should also not occur.

Par 4 Although the level of protection provided by the minor system is basically a decision of the municipality, or owner of the system in the case of private systems, it is suggested that at least a 2-year storm should be used for design purposes. If foundation drains are to be connected by gravity to the storm sewers, significantly higher return frequencies should be used for the design storm.

2.5 RUNOFF COEFFICIENTS

Par 1 The following ranges of runoff coefficients are considered reasonable for design purposes:

Asphalt, concrete, roof areas	0.90 - 1.00
Grassed areas, parkland	0.15 - 0.35
Commercial	0.75 - 0.85
Industrial	0.65 - 0.75
Residential:	
Single Family	0.40 - 0.45
Semi-detached	0.45 - 0.60
Row housing, Town housing	0.50 - 0.70
Apartments	0.60 - 0.75
Institutional	0.40 - 0.75

Par 2 It should be noted that the runoff coefficient for any particular type of area should be taken from the upper portion of the above ranges to account for antecedent precipitation conditions when expected runoff is being calculated for high intensity, less frequent storms. The lower end of the range may be used for shorter recurrence interval storms under conditions of moderate to flat slopes and permeable soils.

2.6 TIME OF CONCENTRATION

Par 1 The time of concentration is the time required for flow to reach a particular point in the sewer system from the most remote part of the drainage area. It

includes not only the travel time in the sewers, but also the inlet time, or time required to flow overland into the sewer system.

Par 2 Inlet times should be calculated, rather than relying upon arbitrary minimum or maximum times. The calculation, however, must be based upon the overland flow route which will exist when the sewer system has been fully developed to the drainage limit. In the case of single family residential areas, calculations will not be required if a maximum inlet time of 10 minutes has been used.

3.0 SEWER DESIGN*

3.1 FLOW FORMULAE AND ROUGHNESS COEFFICIENT

Par 1 It is recommended that storm sewer capacities be calculated using the Manning formula with a roughness coefficient (n) of no lower than 0.013 for all smooth-walled pipe materials.

3.2 ALLOWABLE FLOW VELOCITIES

Par 1 Minimum - 0.8 m/s (2.5 fps)

Maximum - 6 m/s (20 fps)

3.3 MINIMUM PIPE SIZES

Par 1 a) Storm Sewers

- 250 mm (10 in.)

b) Catch basin leads

Single - 200 mm (8 in.)

Double - 250 mm (10 in.)

c) Building storm drains

- as per requirements of Plumbing Code (Ont. Reg. 647).

3.4 DEPTH OF COVER

Par 1 Although it is not always possible due to the

* Refer also to "Guidelines for the Design of Sanitary Sewage Systems" for a more complete discussion of hydraulics, pipe design, depth of cover, manhole spacing, etc.

elevations of receiving streams, etc., storm sewers should be placed below the depth of frost penetration.

3.5 MANHOLE SPACING

Par 1 a) At all changes in grade, alignment (except for curvilinear sewers) or pipe size;

b) Sewers 250 to 450 mm (10 to 18 in.) line spacing - up to 120 m (394 ft.);

c) Sewers 500 to 750 mm (20 to 30 in.) line spacing - up to 150 m (492 ft.);

d) Sewers larger than 750 mm (30 in.) line spacing - greater than 150 m (492 ft.).

3.6 MANHOLE DESIGN

Par 1 See "Guidelines for the Design of Sanitary Sewage Systems".

3.7 SEPARATION OF SEWERS FROM WATER SUPPLY SYSTEMS

Par 1 The Ministry has policy and guidelines regarding the separation of storm and sanitary sewers from water supply systems. See Appendix A for the requirements of this policy and the related guidelines.

3.8 CATCH BASINS

Par 1 a) Catch basins may be installed with, or without, sumps.

b) Catch basins should be provided at adequate intervals to ensure that the road drainage is able to be intercepted up to the capacity of the storm sewer. The spacing will vary with the road width, grade and crossfall and with the design storm frequency. The spacing will also be affected by the location of pedestrian crossing points, intersections, low points, driveway depressions, etc. In general, for pavement widths up to 9.8 m (32 ft.) with 2 per cent crossfall the maximum spacing should be as follows:

ROAD GRADIENT	MAXIMUM SPACING
0% to 3%	up to 107 m (350 ft.)
3.1% to 4.5%	up to 91 m (300 ft.)
over 4.5%	up to 76 m (250 ft.)

c) Catch basin manholes are permitted.

3.9 CURVILINEAR SEWERS

Par 1 Curvilinear sewers are permitted provided the operating authority has equipment to clean such sewer systems.

3.10 ACCEPTABLE ALTERNATE SEWER MATERIALS

Par 1 Acceptable sewer materials include asbestos cement, concrete, vitrified clay, polyvinyl chloride, polyethylene and corrugated metal. See "Guidelines

for the Design of Sanitary Sewage Systems" for further discussion of pipe materials, pipe strength, specifications, etc.

3.11 DESIGN CALCULATIONS

Par 1 All applications for storm sewer approval must be accompanied by design calculations. These calculations are generally best presented in a form similar to that shown in Appendix B.

4.0 ROOF DRAINAGE

Par 1 Where lot sizes and surface conditions permit, it is preferable that roof drainage discharge onto the ground surface via splash pads rather than connect directly into the storm sewer system.

5.0 FOUNDATION DRAINAGE

Par 1 The connection of foundation drains to storm sewers will be at the discretion of the municipality. In arriving at a decision in this regard, the municipality should consider the following factors:

a) possibility of storm sewer surcharging;
b) difference in elevation between basement floor slabs and storm sewer obverts;
c) possibility of foundation damage and flooding which could result due to back up into private storm drains.

APPENDIX A

Proposed Policy for Location of Sewers and Watermains

1. Sewers and watermains located parallel to each other should be constructed in separate trenches maintaining the maximum practical horizontal separation.

2. In cases where it is not practical to maintain separate trenches or the recommended horizontal separation cannot be achieved the Ministry of the Environment may allow deviation from the above.

Guidelines

1. GENERAL

Par 1 Ground or surface water may enter an opening in the water distribution system with the occurrence of a negative internal/positive external pressure condition. Ground water may enter the distribution system at leaks or breaks in piping, vacuum-air relief valves, blow-offs, fire hydrants, meter sets, outlets, etc. Water pressure in a part of the system may be reduced to a potentially hazardous level due to shut downs in the system, main breaks, heavy fire demand, high water usage, pumping, storage, or transmission deficiency.

Par 2 The relative location of sewers and watermains (including appurtenances) and types of material used for each system are important considerations in designing a system to minimize the possibility of contaminants entering the water distribution system.

Par 3 The use of, and adherance to, good engineering and construction practice will reduce the potential for health hazard in the event of the occurrence of conditions conducive to ground water flow into the water distribution system.

2. PARALLEL INSTALLATIONS

Par 1 1. Under normal conditions, watermains should be laid with at least 2.5 metres horizontal separation from any sewer or sewer manhole; the distance shall be measured from the nearest edges.

a) Under unusual conditions, where a significant portion of the construction will be in rock, or where it is anticipated that severe dewatering problems will occur or where congestion with other utilities will prevent a clear horizontal separation of 2.5 metres, a watermain may be laid closer to a sewer, provided that the elevation of the crown of the sewer is at least 0.5 metres below the invert of the watermain. Such separation shall be of in-situ material or compacted backfill.

b) Where this vertical separation cannot be obtained, the sewer shall be constructed of materials and with joints that are equivalent to watermain standards of construction and shall be pressure tested to assure water tightness.

c) In rock trenches, facilities should be provided to permit drainage of the trench to minimize the effects of impounding of surface water and/or leakage from sewers in the trench.

3. CROSSINGS

Par 1 1. Under normal conditions, watermains shall cross above sewers with sufficient vertical separation to allow for proper bedding and structural support of the watermain and sewer main.

Par 2 2. When it is not possible for the watermain to cross above the sewer, the watermain passing under a sewer shall be protected by providing:

a) A vertical separation of at least 0.5 metres between the invert of the sewer and the crown of the watermain.

b) Adequate structural support for the sewers to prevent excessive deflection of joints and settling.

c) That the length of water pipe shall be centred at the point of crossing so that the joints will be equidistant and as far as possible from the sewer.

4. SERVICE CONNECTIONS

Par 1 Wherever possible, the construction practices outlined in this guideline should apply with respect to sewer and water services.

5. TUNNEL CONSTRUCTION

Par 1 If the "Tunnel" is of sufficient size to permit a

man to enter the tunnel for the purposes of maintenance, etc., it is permissible to place the sewer and watermain through the tunnel providing the watermain is hung above the sewer.

Par 2 If the tunnel is sized only to carry the pipes, or if the tunnel is subject to flooding, the sewer shall be constructed of materials and with joints that are equivalent to watermain standards of construction and shall be pressure tested to assure water tightness.

6. DESIGN FACTORS

Par 1 When local conditions do not permit the desired spacing, or water and sewer lines or other conditions indicate that detailed investigations are warranted, the following factors should be considered in the design of the environment and relative location of water and sewer lines.

Par 2 This list of factors should be considered as a guide and not all inclusive.

a) Materials, types of joints and identification for water and sewage pipes;

b) Soil conditions, e.g. in-situ soil and backfilling materials and compaction techniques;

c) Service and branch connections into the watermain and sewer lines;

d) Compensating variations in the horizontal and vertical separations;

e) Space for repair and alterations of water and sewer pipes;

f) Off-setting of pipes around manholes;

g) Location of ground-water table and trench drainage techniques;

h) Other sanitary facilities such as septic tanks and tile fields, etc.

7. VALVE, AIR RELIEF, METER AND BLOW-OFF CHAMBERS

Par 1 a) Chambers or pits containing valves, blow-offs, meters or other such appurtenances to a water distribution system shall not be connected directly to any storm or sanitary sewer, nor shall blow-offs or air-relief valves be connected directly to any sewer.

b) Such chambers or pits shall be drained to the surface of the ground where they are not subject to flooding by surface water; to absorption pits underground or to a sump within the chamber where ground water level is above the chamber floor.

8. RESERVOIRS BELOW NORMAL GROUND SURFACE

Par 1 Sewers, drains, and similar sources of contamination should be kept at least 15 m (50 ft.) from the reservoir. Mechanical-jointed water pipes, pressure

tested in place to 350 kPa (50 psi) without leakage, may be used for gravity sewers at lesser separations.

9. UNACCEPTABLE INSTALLATIONS

Par 1 No watermain or service line shall pass through or come into contact with any part of a sewer or sewer manhole.

APPENDIX B

STORM SEWER DESIGN SHEET

$Q = 2.78\,AIR$

Where Q = peak flow in litres per second (L/s)

A = area in hectares (ha)

I = rainfall intensity in millimetres per hour (mm/h)

R = runoff coefficient

LOCATION			AREAS (ha)			Indiv	Accum	Time of	Rainfall	Peak Flow	SEWER DATA								
STREET	FROM	TO	R=	R=	R=	2.78 AR	2.78 AR	Conc	Intensity I	Q (L/s)	Type of Pipe	Diameter (mm)	Slope (%)	Length (m)	Capacity (L/s) n=____	Velocity (m/s)	Time of Flow (minutes)		

DESIGN	PROJECT
CHECKED	
DATE	

SHEET No

____ of ____

APPENDIX C

Bibliography

1. "Manual of Practice on Urban Drainage", The Urban Drainage Subcommittee of the Canada - Ontario Agreement on Great Lakes Water Quality; D. F. Rhodes Secretary, Canada - Ontario Agreement, Ontario Ministry of the Environment, Pollution Control Branch, 135 St. Clair Avenue West, Toronto, Ontario. M4V 1P5

2. "Municipal Works Design Manual", Municipal Engineers Association, Office of the President, 4310 Queen Street, Niagara Falls, Ontario.

3. "Regulation 647, Revised Regulations of Ontario, Plumbing Code", Ontario Government, Queen's Park, Toronto, Ontario.

GUIDELINES FOR THE DESIGN

OF

SANITARY SEWAGE SYSTEMS

MAY 1979

The Honourable
Harry C. Parrott, D.D.S.,
Minister

Graham W. S. Scott,
Deputy Minister

GUIDELINES FOR THE DESIGN

OF

SANITARY SEWAGE SYSTEMS

MAY 1979

MUNICIPAL AND PRIVATE APPROVALS SECTION
ENVIRONMENTAL APPROVALS BRANCH

MINISTRY
OF THE
ENVIRONMENT

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Following this initial review, revisions were made and the document underwent a final review by committees consisting of representatives from the local municipalities within the various District, Metropolitan, and Regional Municipalities. The present form of the guideline includes changes suggested by these latter committees.

TABLE OF CONTENTS

1.0 INTRODUCTION

Par 1 This edition of guidelines has been prepared as a revision to the previous issue No. 2, dated October 1975.

Par 2 These guidelines are primarily intended to outline minimum acceptable levels of servicing to assist consulting engineers, municipal engineering staff, and other designers in the preparation of sanitary sewage system designs that will meet the approval requirements of the Ministry of the Environment. It should be noted that other approval authorities, such as the municipalities in which the works will be constructed, may have servicing standards that exceed the requirements of these guidelines. The designer should therefore ensure that he is aware of the requirements of all other approving authorities prior to submitting designs for approval.

Par 3 Although some aspects of the guidelines relate only to municipal services, the guidelines are meant to apply where applicable to other sewage systems serving developments such as mobile home parks, condominiums, etc., which also require Ministry of the Environment approval under the Ontario Water Resources Act.

Par 4 To allow the guidelines to be more simply modified in future, and to permit faster reference by the

users to specific paragraphs of the text, the guidelines have been broken down into numbered sections and paragraphs as shown along the left hand margin of each page.

Par 5 As a final point, it must be emphasized that this document contains design guidelines. These should not be confused with standards or regulations which must be absolutely complied with, in order to obtain approval. It is not the intention of the Ministry of the Environment to stifle innovation. Whenever a designer can demonstrate that environmental and/or health conditions can be safeguarded by alternative approaches, such methods will be considered for approval.

2.0 SANITARY SEWER SYSTEMS

2.1 SEPARATE vs COMBINED SEWERS

Par 1 All new sewer construction within the Province of Ontario should be of the "separate" type, with all forms of storm and groundwater being excluded to the greatest possible extent. "Combined" sewers will only be permitted on a case by case basis, with the designer being required to provide the justification for the proposed method of servicing. Servicing extensions using combined sewers will only be considered in areas where such systems already exist.

2.2 DESIGN PERIOD AND TRIBUTARY AREA

Par 1 Wherever possible, the design of sanitary sewers should be based on the ultimate sewage flows expected from the tributary area. Tributary areas need not necessarily be restricted to current municipal limits. In the cases, however, where the tributary area is poorly defined, or where the financial burden on present users would be too severe, the sewage system design may be based on more restricted approaches. In these cases, however, the design period should be at least 20 years.

Par 2 For Provincially funded sewage schemes, refer to

Appendix A, for the additional Ministry of the Environment requirements.

2.3 DESIGN POPULATIONS AND FUTURE LAND USES

Par 1 For purposes of estimating future sewage flow rates, for municipal sewage collection systems, the designer should make reference to the Official Plan (or Draft Official Plan) of the municipality. Such official plans will contain future population densities and land uses.

Par 2 If no Official Plan, or Draft, exists, the designer should size sanitary sewers for population densities of at least 25 persons per gross hectare (10 ppa). The minimum level of population density will generally be suitable for only rural municipalities. If the municipality already has higher population densities, the designer should use similar, or higher, densities for new growth areas.

2.4 ENERGY REQUIREMENTS

Par 1 In view of the rising cost of energy and the possibility of future energy shortages, designers should attempt to minimize the number of sewage pumping stations required in sewage collection systems. In many instances, deeper gravity sewers, inverted siphons or aerial sewers, may not only

eliminate the need for pumping stations, but they may prove to be economically more attractive in the long-term.

Par 2 It is recommended that designers evaluate gravity sewer alternatives to sewage pumping stations by comparing the total of the capital, operating, and maintenance costs of the two approaches. To make such a comparison, it is suggested that all annual costs be expressed as equivalent capital costs.

Par 3 To compensate for future increases in such items as labour and energy costs and to allow for financing interest rates, it is suggested that the present day annual costs be capitalized by multiplying by a factor of 15 for labour and a factor of 18 for energy related expenses. For a more detailed discussion of this subject and the methods of arriving at the above factors, the reader should make reference to the Ministry publication, "Guidelines for Energy Conservation in the Design of Sewage Systems and Treatment Facilities in the Province of Ontario", August 1977.

Par 4 If, in the review of applications by the Ministry of the Environment, it appears that more cost effective and/or less energy intensive alternatives could have been proposed, the designer may be

requested to submit detailed comparisons of the proposal and possible alternatives.

2.5 HYDRAULIC DESIGN

2.5.1 Design Sewage Flows

Par 1 Sanitary sewage flows are made up of waste discharges from residential, commercial, institutional, and industrial establishments, plus extraneous non-waste flow components from such sources as groundwater, and surface runoff.

Par 2 The peak sewage flow rates for which sewer system capacity is to be provided, must be calculated with due consideration being given to all the above-mentioned possible flow contributors, for present and future conditions. In addition to being able to carry the peak flows, sewers must be able to develop sufficient flow velocity to transport the sewage solids, thus avoiding deposition and the development of nuisance conditions under lesser flow conditions.

2.5.1.1 Domestic Sewage Flows

Par 1 The following criteria should be used in determining peak sewage flows from residential areas, including single and multiple housing, mobile home parks, etc.:

a) Design population derived from drainage area and expected maximum population over design period.

b) Average daily domestic flow (exclusive of extraneous flows[1]) of from 225 to greater than 450 L/cap.d (50 to greater than 100 gpcd).

c) Peak extraneous flow (including peak infiltration and peak inflow) of from 0.14 to greater than 0.28 L/s per gross hectare (0.002 to greater than 0.004 cfs/gross acre).

d) Peak domestic sewage flows to be calculated by the following equation -

$$Q(d) = \frac{PqM}{86.4} + IA$$

where Q(d) = Peak domestic sewage flow (including extraneous flows) in L/s.

P = Design population, in thousands.

q = Average daily per capita domestic flow in L/cap.d (exclusive of extraneous flows).

M = Peaking factor (as derived from Harman Formula

$$M = 1 + \frac{14}{4+P^{0.5}}, \text{ or}$$

Babbit Formula

$$M = \frac{5}{P^{0.2}}, \text{ or as}$$

determined from flow studies

[1]See Section 2.5.1.4 for discussion of Extraneous Flow Allowances

for similar developments in the same municipality). The minimum permissible peaking factor shall be 2.0.

I = Unit of peak extraneous flow, in L/s per hectare.

A = Tributary area in gross hectares.

2.5.1.2 Commercial and Institutional Sewage Flows

Par 1 The sewage flows from commercial and institutional establishments vary greatly with the type of water-using facilities present in the development, the population using the facilities, the presence of water metering, the extent of extraneous flows entering the sewers, etc.

Par 2 In general, the method of estimating sewage flows for large commercial areas is to estimate a population equivalent for the acreage covered by the development and then calculate the sewage flows on the same basis as discussed in the previous section. A population equivalent of 85 persons per gross hectare (35 ppa) is often used. It is also necessary to calculate an appropriate peaking factor and select a representative unit of peak extraneous flow.

Par 3 For individual commercial and institutional uses the following sewage flow rates are commonly used for design. Where a range is stated the lower figure is the minimum requirement.

	Sewage Flows[2] (Avg. Daily)
Shopping Centres	- 2500-5000 L/1000 m^2.day (based on total floor area) (50-100 gpd/1000 ft^2)
Hospitals	- 900-1800 L/bed.day (200-400 gpd/bed)
Schools	- 70-140 L/student.day (15 to 30 gpd/student)
Campgrounds	- 225-570 L/campsite.day (50 to 125 gpd/campsite)

Par 4 The peaking factors applicable for sewage flows from individual establishments will be similar to the peak water usage rates discussed in Section 2.1.1.2 of the "Guidelines for the Design of Water Distribution Systems".

2.5.1.3 Industrial Sewage Flows

Par 1 Peak sewage flow rates from industrial areas vary greatly with the extent of the area, the types of industries present, the provision of in-plant treatment or regulation of flows, the presence of cooling waters in the sanitary sewer system, etc.

[2]Unit sewage flow rates exclusive of infiltration.

Due to the occasional presence of individual industrial water supplies, the rates of water supply from municipal systems into industrial areas will not always be indicative of the sanitary sewage flows to be expected. Conversely, the discharge of good quality cooling water, originally derived from municipal supplies, into storm sewers or surface water courses, may result in lower flows in sanitary sewers than would be expected based on municipal water usage.

Par 2 The calculation of design sewage flow rates for industrial areas is, therefore, difficult. Careful control over the type of industry permitted in new areas is perhaps the most acceptable way to approach the problem. In this way, a reasonable allowance can be made for peak industrial sewage flows for an area and then the industries permitted to locate in the area can be carefully monitored to ensure that the overall allowances are not exceeded. Industries with the potential to discharge sewage at higher than the accepted rate could either be barred from the area, or be required to provide flow equalization and/or off-peak discharge facilities.

Par 3 Some typical sewage flow allowances for industrial areas are 35 m^3/hectare.day (3000 gpad) for light industry, and 55 m^3/hectare.day (5000 gpad) for

heavy industry. These are average flow rates and the peak sewage flow rates vary with the size of the industrial area as shown in Appendix B.

Par 4 See Appendix A for Guidelines on Industrial Sewage Flow Allowances for Provincially-financed projects.

2.5.1.4 <u>Extraneous Sewage Flows</u>

Par 1 When designing sanitary sewer systems, allowances must be made for the leakage of groundwater into the sewers and building sewer connections (infiltration) and for other extraneous water entering the sewers from such sources as leakage through manhole covers, foundation drains, roof downspouts, etc.

Par 2 Due to the extremely high peak flows that can result from roof downspouts, they should not, in any circumstance, be connected directly, or indirectly via foundation drains, to sanitary sewers. The Ministry of the Environment also discourages the connection of foundation drains to sanitary sewers. Studies which have been conducted by the Ministry show that flows from this source can result in gross overloading of sewers, pumping stations and sewage treatment plants for extended periods of time. The Ministry recommends that foundation drainage be directed either to the surface of the ground or into a storm sewer system,

if one exists.

Par 3 The method of connection of foundation drains to storm sewers must be given careful consideration. Only in cases of deep storm sewers, where surcharging up to the level of basements under severe storm conditions is unlikely, should foundation drains be connected by gravity to storm sewers. Under other conditions, connections to storm sewers via sump pumps can be used, or else, a separate foundation drain collector sewer can be installed.

Par 4 The amount of groundwater leakage directly into the sewer system (infiltration) will vary with the quality of construction, type of joints, ground conditions, level of groundwater in relation to pipe, etc. Although such infiltration can be reduced by proper design and construction, it cannot be completely eliminated and an allowance must be made in the design sewage flows to cover these flow contributors. Despite the fact that these allowances are generally referred to as infiltration allowances, they are intended to cover the peak extraneous flows from all sources likely to contribute non-waste flows to the sewer system. The infiltration allowances used for sewer design should not be confused with leakage limits used for acceptance testing following construction. The latter allowances are significantly lower and apply

to a sewer system when the system is new and generally without the private property portions of the building sewers constructed.

Par 5 Some typical peak extraneous flow allowances used for design are as follows:

a) 0.14 to 0.28 L/s.ha (gross) (0.002 to 0.004 cfs/gross acre).

b) 5,650 to 11,300 L/d.km (2000 to 4000 gpd/mile) of total sewer system including main sewers, laterals, and building sewer connections.

c) 22 to 44 L/d.mm(dia).km (200 to 400 gpd/in. (dia)/mile) of total sewer system.

d) 250-500 L/cap.d (55 to 110 gpcd).

Par 6 The above allowances assume strict control by the municipalities of building connections (i.e. no roof drains or foundation drains connected directly or indirectly to the sanitary sewer system). Where this is not the case, higher allowances may be necessary.

2.5.2 Flow Formula and Roughness Coefficient

Par 1 The Ministry of the Environment recommend that sanitary sewers be designed using either Kutter's or Manning's formula and a roughness coefficient (n) of no lower than 0.013 for all smooth-walled pipe materials.

Par 2 The Manning formula, which is the most commonly used formula for calculating sewer capacity is as follows:

$$Q = \frac{7.8546 \times 10^{-6}}{n} D^2 . R^{2/3} . S^{1/2}$$

Where Q = Flow capacity of sewer (in L/s)

D = Inside diameter of pipe (in mm)

R = Hydraulic radius of pipe (in mm)

S = Sewer slope

Par 3 For small diameter sewers (less than 900 mm (3 ft.)), Kutter's formula gives a more conservative estimate of sewer capacity. For this reason, Kutter's formula is usually used to calculate minimum acceptable sewer slopes (see Section 2.5.4).

2.5.3 Minimum and Maximum Velocities

Par 1 All sewers should be designed with such slopes that they will achieve a mean sewage flow velocity when flowing full of at least 0.6 m/s (2 fps). In cases where the flow depths in the sewers under peak flows will not be 0.3 of the diameter, or greater, the actual peak flow velocity should be calculated using a hydraulic-elements chart and the slope increased to achieve adequate flushing velocities. In certian circumstances, such as where increased slopes would require deepening of extensive sections of the sewage collection system, peak sewage flow velocities of less than 0.6 m/s may be

acceptable provided that the municipality accepts the increased maintenance requirements.

Par 2 It should be remembered that sewers achieving flow velocities less than those required for self-cleansing of grit and organics will have increased maintenance expenses due to the deposition of solids and need for frequent cleaning. These increased maintenance costs should be compared with the costs which would have been incurred if sewers were deepened to achieve adequate slopes.

Par 3 In sizing sanitary sewers and selecting sewer slopes, consideration must be given to possible sulphide generation problems. Sulphide problems can be minimized by designing for sewers to flow less than full under peak flow conditions and to flow at velocities of 0.6 m/s (2 fps), or more. Reference should be made to the EPA publication "Sulphide Control in Sanitary Sewerage Systems" for more information.

Par 4 The velocities in sanitary sewer systems should be limited to no more than 3 m/s (10 fps), especially where high grit loads are expected. Higher velocities should be avoided unless special precautions are taken to protect against displacement and pipe erosion.

2.5.4 Minimum Sewer Slopes

Par 1 All sewers should be designed and constructed to give minimum velocities, when flowing full, of not less than 0.6 m/s (2.0 fps), based on Kutter's formula using an "n" value of 0.013. The following are the minimum slopes which should be provided:

Sewer Size	Minimum Slope in Metres per 100 Metres
200 mm (8 in.)	0.40
250 mm (10 in.)	0.28
300 mm (12 in.)	0.22
350 mm (14 in.)	0.17
375 mm (15 in.)	0.15
400 mm (16 in.)	0.14
450 mm (18 in.)	0.12
525 mm (21 in.)	0.10
600 mm (24 in.)	0.08
675 mm (27 in.)	0.067
750 mm (30 in.)	0.058
900 mm (36 in.)	0.046

Par 2 To achieve 0.6 m/s (2.0 fps) flow velocities in sewers which will flow less than 1/3 full, steeper slopes than given above must be used. For instance, the minimum slopes mentioned above would have to be doubled when depth of flow is only 1/5 full, and quadrupled when depth of flow is only 1/10 full to achieve 0.6 m/s (2.0 fps) flow velocity.

2.5.5 Allowances for Hydraulic Losses at Sewer Manholes

Par 1 The following minimum allowances should be made for hydraulic losses incurred at sewer manholes:

	Invert Drop
a) straight run	Grade of sewer

b) 45^{o} turn 0.03 m (0.1 ft.)

c) 90^{o} turn 0.06 m (0.2 ft.)

d) Junctions and transitions See Appendix C

Par 2 Although the above invert drops will be adequate for sewers flowing at velocities at the low end of the acceptable range, the required drops should be calculated for high velocity sewers.

2.5.6 Design Calculations

Par 1 When submitting applications to the Ministry of the Environment for approval, they should be accompanied by sewer design calculations presenting in tabular form the required capacity, sewer size, sewer slope, roughness coefficient used, pipe capacity provided, flow velocity when flowing full, and depth of flow and actual flow velocity at peak flow if depth of flow is less than 0.3 of the pipe diameter.

Par 2 A typical sewer design sheet is shown in Appendix D.

2.6 SEWER SYSTEM LAYOUT

Par 1 For general discussions of sanitary sewer layout techniques, the designer should refer to such design manuals and texts as the following:

a) "Design Manual for Sewers and Watermains" - sponsored by the Municipal Engineers Association

and the Ministry of the Environment.

b) "Design and Construction of Sanitary and Storm Sewers", WPCF Manual of Practice No. 9.

c) "Wastewater Systems - Pipes and Piping" Manual of Practice Number Three, Water and Wastes Engineering.

Par 2 Some aspects of sewer system layout are discussed in the following sections. Since the specific requirements of the municipalities may exceed the guidelines of the Ministry of the Environment, the designer should become acquainted with municipal standards as well.

2.6.1 Minimum Sewer Sizes

Par 1 To allow for ease of future maintenance and cleaning, the Ministry of the Environment recommends that no sewer smaller than 200 mm (8 in.) in diameter be used in sanitary sewage collection systems. This same criteria is intended to apply to collection systems on private property serving developments such as condominiums, mobile home parks, townhouses, etc.

Par 2 Building sewer connections from buildings to collector sewers may be as small as 100 mm (4 in.) in diameter, depending upon the pipe slope and upon the number of fixture units in the building served. Double building sewer connections may be

permitted.

2.6.2 Depth of Cover

Par 1 In general, sanitary sewers should be laid at sufficient depth to receive sewage from basements by gravity drainage and to prevent freezing and damage due to frost heaving. For lands substantially below street level, however, it will usually be more economical to require pumpage from these buildings into the sewer rather than deepen the sewer to accommodate a limited number of low lying properties. To allow for gravity drainage from basements, sewer inverts must normally be at least 0.9 to 1.5 m (3 to 5 ft.) below basement floor levels.

Par 2 To prevent frost heaving and freezing, sewers in Southern Ontario should have at least 1.5 to 1.8 m (5 to 6 ft.) of cover. Refer to the "Guidelines for the Design of Water Distribution Systems" for a discussion of the effects of frost on underground piping systems.

Par 3 As a general guide, the depths of frost penetration for areas of Ontario are as follows:

	Frost Penetration
Southwestern Region	1.5 to 1.8 m (5-6 ft.)
West-Central Region	1.7 to 2.0 m (5½-6½ ft.)

Central Region	1.7 to 2.0 m (5½-6½ ft.)
Southeastern Region	1.7 to 2.1 m (5½-7 ft.)
Northeastern Region	1.8 to 2.4 m (6-8 ft.)
Northwestern Region	2.1 to 2.6 m (7-8½ ft.)

Par 4 For any particular location, the depth of frost penetration may differ from the above ranges and reference should either be made to local records or data available from the Atmospheric Environment Branch of Transport Canada, or the Ministry of Transportation and Communications publication "Frost Depth Penetrations/Ontario 1970-74".

Par 5 Other factors which can affect sewer depth requirements are interference with other utilities at crossings (both main sewer and building sewer vertical alignments can be affected by storm sewers, watermains, gas mains, etc.) and length of building sewer connections.

2.6.3 Sewer Location

Par 1 Sanitary sewers are generally located at or near the centreline of roads to allow buildings on both sides of the street to be serviced with approximately the same lengths of building sewers. Municipalities generally have standards relating to the preferred location of services. These standards will be acceptable to the Ministry provided that they do not place the sewers (sanitary and/or storm) too

close to water facilities, as prohibited by Ministry policy. See Appendix E for the Ministry policy covering such matters.

2.6.4 Manhole Spacing

Par 1 Experience with maintenance and repair operations has shown that the acceptable spacing for manholes is 90 to 120 m (300 to 400 ft.) for sewers 200 to 450 mm (8 to 18 in.) in diameter, and for sewers 450 to 750 mm (18 to 30 in.) in diameter spacings of up to 150 m (500 ft.) may be used. Larger sewers may use greater manhole spacing.

Par 2 For any particular municipality, the acceptable manhole spacing will vary depending upon the sewer cleaning equipment available. Some municipalities may require shorter spacing intervals. The above limits may, therefore, be exceeded provided the applicant can demonstrate the suitability of equipment available to handle such spacing.

Par 3 Manholes should be located at all junctions, changes in grade, size, or alignment (except with curvilinear sewers), and termination points of sewers.

Par 4 See Section 2.8.1. for other manhole design guidelines.

2.7 PIPE DESIGN

2.7.1 Pipe Strength Requirements

Par 1 Sewer pipe selected for any particular application must be able to withstand, with an adequate margin of safety, all the combinations of loading conditions to which it is likely to be exposed.

Par 2 Pipe used in gravity flow sewers is usually not subjected to internal pressure, except to a small degree under conditions of surcharge. Therefore, in the design of sewer pipe, internal pressure is usually not a significant factor. In special cases, involving excessive surcharge, such as in inverted siphons, pressure pipe must be used and reference should be made to Section 4.0, Pipe Design, of the "Guidelines for the Design of Water Distribution Systems".

Par 3 On the other hand, sewer pipe installed in a back-filled trench carries the external static and live loads placed on it. The factor of external load is, therefore, very important in the design of sewer pipe, regardless of the material used.

Par 4 The design procedures to be used to calculate earth loading, superimposed loads, and the supporting strength of sewer pipe under various types of installations and bedding conditions is well

covered in a number of design manuals, texts, pipe supplier's catalogues, etc. A list of some of the better known references is included in Section 2.6. Some additional references are as follows:

a) "Concrete Pipe Design Manual", prepared by American Concrete Pipe Association, 1501 Wilson Blvd., Arlington, Virginia. 22209.

b) "Handbook of Steel Drainage and Highway Construction Products", published by American Iron and Steel Institute, 150 East 42nd Street, New York. New York. 10017.

c) "Plastic Pipe in Sanitary Engineering", by Lars-Eric Janson, Celanese Piping Systems, 4300 Cemetary Rd., Hilliard, Ohio. 43026.

d) Pipe supplier's catalogues.

Par 5 Recent studies have shown that the penetration of frost into the ground causes increases in the earth load on buried pipes. These studies indicated that earth loads roughly doubled despite the fact that the frost penetration did not reach the tops of the pipes. The earth loadings prior to frost penetration were approximately equivalent to calculated prism loads. In these experiments, it is interesting to note that the loading increased to double the normal earth load as the frost penetration increased, but the closest that the frost layer came to the pipes was 0.22 m (0.75 ft.). It is,

therefore, possible that higher loadings would occur if the frost penetrated closer to the pipe.

Par 6 These increased external loads caused by frost may cause beam breaks in the pipe when bedding is non-uniform. This points to the need for proper attention to the installation of the pipe bedding. It also suggests that great care must be taken in the selection of pipe materials, pipe classes and bedding types.

Par 7 For plastic gravity sewer pipe, the designer is referred to Appendix F, where the Ministry policy and guidelines for such pipe are outlined.

2.7.2 Alternate Pipe Materials

Par 1 The acceptable alternate pipe materials for sanitary sewer systems are as follows:

a) Asbestos-cement

b) Concrete

c) Polyethylene (PE)

d) Polyvinyl Chloride (PVC)

e) Vitrified Clay

Par 2 In special circumstances, other materials such as ductile iron and steel may also be used, but since their use is relatively limited, they will not be covered in these guidelines.

Par 3 Pipe selected for gravity sewer systems shall have

been manufactured in conformity with the latest standards issued by the American Society for Testing Materials or preferably the Canadian Standards Association. In the absence of such standards, pipe manufactured in accordance with certain commercial standards, if acceptable to the Ministry of the Environment, may be selected.

Par 4 For sewer applications requiring pressure pipe, reference should be made to Section 4.0, Pipe Design, of the "Guidelines for the Design of Water Distribution Systems".

Par 5 See Appendix F for the Ministry's "Policy and Guidelines to Govern the Use of Plastic Pipe for Buried, Gravity-Flow Sewers".

Par 6 In choosing a pipe material, the designer should consider the following factors:

a) Flow characteristics - friction coefficient;
b) Life expectancy and use experience;
c) Resistance to scour;
d) Resistance to acids, alkalis, gases, solvents, etc.;
e) Ease of handling and installation;
f) Physical strength;
g) Type of joint - watertightness and ease of assembly;
h) Availability and ease of installation of

fittings and connections;

i) Availability in sizes required; and

j) Cost of materials, handling, and installation.

2.7.2.1 Asbestos-Cement

Par 1 Non-pressure asbestos-cement sewer pipe should be manufactured and tested in accordance with the latest revisions of ASTM C428 and C500, respectively. The pipe is available in sizes ranging from 100 to 900 mm (4 to 36 in.) in diameter and in classes 1500, 2400, 3300, 4000 and 5000.

Par 2 The advantages of asbestos-cement pipe is that the pipe is light in weight and comes in long laying lengths (up to 4 m (13 ft.)). The pipe is subject to corrosion by acids and is susceptible to erosion by grit in high velocity sewers.

2.7.2.2 Concrete

Par 1 Non-reinforced concrete pipe from 150 to 450 mm (6 to 18 in.) in diameter and reinforced concrete pipe from 300 to 3000 mm (12 to 120 in.) in diameter are available for gravity sewer use. Non-reinforced and reinforced concrete pipe and pipe joints should be manufactured in accordance with the latest revisions of CSA Standards A257.1, A257.2 and A257.3, respectively, and for Provincially-financed projects, in accordance with the

supplementary requirements of the Ministry of the Environment Standard Specification No. 11.

Par 2 Concrete pipe is available in a wide range of strengths and laying lengths 1.2 to 7.3 m (4 to 24 ft.). As with asbestos-cement pipe, concrete is subject to corrosion by acids, but is less susceptible to erosion by grit.

2.7.2.3 Polyethylene (PE)

Par 1 Polyethylene pipe should be manufactured in accordance with the latest revisions of either CSA B137.0 and B137.1 or CGSB 41-GP-25. The CSA Standards cover pipe up to and including 150 mm (6 in.) in diameter and the CGSB Standard covers nominal sizes from 90 to 1200 mm (3.5 to 48 in.) diameter. See Appendix F for the policy and guidelines of the Ministry relating to plastic, gravity-flow sewers.

Par 2 The advantages of polyethylene pipe include its light weight, tight joints, long laying lengths and corrosion resistance.

2.7.2.4 Polyvinyl Chloride (PVC)

Par 1 Polyvinyl chloride pipe should be manufactured in accordance with the latest revisions of CSA B137.0 and B137.3 or ASTM D3034. These specifications cover pipe up to and including 300 mm (12 in.) diameter. See Appendix F for the policy and guide-

lines of the Ministry relating to plastic, gravity-flow sewers.

Par 2 The advantages of PVC pipe include its light weight, long laying lengths, tight joints and corrosion resistance.

2.7.2.5 Vitrified Clay

Par 1 Vitrified clay pipe is manufactured in sizes ranging from 100 to 1050 mm (4 to 42 in.) diameter. Vitrified clay pipe and fittings should be manufactured in accordance with the latest revisions of CSA Specification A60.1 and A60.3, respectively.

Par 2 The advantages of vitrified clay pipe are its resistance to corrosion by acids and its resistance to erosion by grit scouring.

2.8 SEWER APPURTENANCES

2.8.1 Manholes

Par 1 Manholes should be provided on sewer systems at the locations discussed in Section 2.6.4. Manhole design should be as follows:

a) Minimum Diameter - In general 1200 mm (48 in.), or sewer diameter plus 600 mm (2 ft.), whichever is greater, for sewers up to 1050 mm (42 in.). "T" manholes may be used for sewers 1200 mm (48 in.) and larger.

b) Drop Manholes - Should be used where invert levels of inlet and outlet sewers differ by 0.9 m (3 ft.), or more.

c) Channel and Benching - The channel depth should be at least to the spring line of the pipe for 200, 250 and 300 mm (8, 10 and 12 in.) sewers; and at least to three-fourths of the pipe for 375 mm (15 in.) and larger sewers. Channels should have a steel trowel finish.

Benching should be at a slope of at least 1:12 and not greater than 1:8. Benching should have a wood float finish.

d) Manhole Bases - Precast bases may be used for manholes up to 9 m (30 ft.) deep.

e) Pipe Connections - A flexible joint should be provided on all pipes, within 0.3 m (1 ft.) of the outside wall of the manhole. Concrete bedding to solid ground may be used as an alternate approach.

f) Manhole Steps - 400 mm (16 in.) aluminum or galvanized rungs should be provided at a spacing of 300 to 400 mm (12 to 16 in.).

g) Frost Lugs - Where required, frost lugs should be provided to hold precast manhole sections together.

h) Safety Chains - Should be provided on the downstream side of manholes for sewers 1200 mm (48 in.) in diameter or greater.

i) Safety Landings - Safety landings shall be as per Ministry of Labour requirements.

j) Watertight Covers - Watertight covers should be used where manholes will be subject to flooding. Where significant sections of sewers are provided with watertight manholes, extended vents may be required for the sewer system to prevent excessive sulphide generation.

2.8.2 Sanitary Sewer Service Connections

Par 1 The design of sanitary sewer service connections should be as follows:

a) Minimum Diameter - 100 mm (4 in.), or pipe size needed to satisfy requirement of the Plumbing Code (Ont. Reg. 647).

b) Junction with Main Sewer - If sanitary sewer connection size is more than one-half of the main sewer diameter, the connection should preferably be made via a service tee (or service wye). Smaller connections can be made by tee-saddles, tee-inserts, or bell pieces.

c) Sanitary Sewer Service - Connection Grades -

Desirable grade 2%

Minimum Grade 1%

d) Materials - Sanitary sewer service connections may be constructed using any of the materials outlined in Section 2.7.2, except for polyethylene which is not listed as an acceptable material under the Plumbing Code.

2.8.3 Slope Anchors

Par 1 Sewers of 20% slopes, or greater, should be anchored securely with concrete blocks, or equal, spaced as follows:

a) Grades 20 to 35% - Not over 11 m (36 ft.) centre to centre.

b) Grades 36 to 50% - Not over 7 m (24 ft.) centre to centre.

c) Grades over 50% - Not over 5 m (16 ft.) centre to centre.

2.8.4 Inverted Siphons

Par 1 All inverted siphons should have the following design features:

a) Number of Barrels - at least 2 (with one of the two serving as standby).

b) Minimum Pipe Size - at least 150 mm (6 in.).

c) Velocity at Design Flow for each barrel - 1 m/s (3 fps).

d) Chamber Design - Inlet and outlet chambers; allowance for rodding and flushing operations; provision to isolate barrels for maintenance.

3.0 SEWAGE PUMPING STATIONS

3.1 STATION CAPACITY

Par 1 Sewage pumping stations should at least be able to pump the expected 10-year peak sewage flows with the largest capacity pump out of operation. See Section 2.5.1. for the recommended approach for the calculation of peak sewage flows. For a two pump station, each pump should have sufficient capacity to handle the peak flows. For a three pump station, with the largest pump out of operation, the two remaining pumps operating in parallel should be able to pump the peak sewage flows, etc.

Par 2 Sewage pumping stations should at least be designed so that with minor modifications (pumps, motors or impellor changes), they can handle the 20-year peak sewage flow. Economic evaluation will often show that there is no saving by initially providing the 10-year capacity, then increasing the capacity at a later date. Based upon the experience of the Ministry of the Environment with Ministry-financed projects, the recommended approach is to initially provide the 20-year capacity. It is, of course, preferred that the ultimate anticipated peak flows from the tributary area could be handled with the addition of another pump, and/or forcemain, plus other modifications.

3.2 WET WELL/DRY WELL vs SUBMERSIBLE PUMPING STATIONS

Par 1 Both types of pumping stations are acceptable to the Ministry. As pumping and horsepower requirements increase, wet well/dry well type stations are generally preferred.

Par 2 The typical efficiencies of the two types of pumping systems, along with capital, operating and maintenance costs should be considered when choosing between the two types of stations.

Par 3 Factory-built wet well/dry well pumping stations are acceptable as an alternative to custom-built wet well/dry well stations. For large horsepower installations, the heat dissipation limitations of factory-built pumping stations may render them unsuitable. In evaluating factory-built versus custom-built options, the following factors should be considered:

a) Capital, operating and maintenance costs;
b) Flexibility with respect to maintenance and pumping capacity increases;
c) Anticipated life of the structures;
d) Delivery times and construction scheduling;
e) Safety;
f) Requirement for and availability of skilled labour for installation.

3.3 PUMPING STATION SITE CONSIDERATIONS

Par 1 To allow for servicing, vehicle access to the wet well, dry well and buildings on site must be provided.

Par 2 If internal combustion engines are to be provided within the station, the requirement of Section 8 of the Environmental Protection Act must be satisfied. A separate application for "Air" approval will be necessary. If the isolation from the engine exhaust to the nearest point of impingement is not sufficient to dissipate the air contaminants to within the regulated levels, an exhaust stack may be required.

Par 3 If more than one sewer enters the site, a junction manhole is preferred so that only one inlet to the wet well will be required. Any electrical controls and/or switch gear located outside must be located in a weatherproof enclosure.

3.4 STANDBY POWER

Par 1 The need for standby power at a sewage pumping station will be assessed by the Ministry of the Environment for each pumping station application. To assist in this evaluation, the designer should furnish the information requested in the Ministry's "Guidelines for the Provision of Equipment to

Handle Emergency Conditions (power outages) in New Sewage Works in the Province of Ontario".

Par 2 If standby power is required, it may be provided by means of an emergency standby generator powered by either a diesel engine, a gasoline engine, or a natural gas engine, or by an auxiliary drive system powered by any of the foregoing primary power sources. In consideration of their superior reliability, diesel engines are recommended. In certain instances, portable generators, portable gasoline or diesel driven pumps, or the provision of an additional hydro feed line may satisfy the Ministry's standby requirements.

Par 3 Whatever the method of providing standby power, it should be capable of powering enough pumps to handle the peak sewage flows. If the generator and motor are not sized to simultaneously run the duty and standby pumps, the standby pump should be locked out in standby mode.

3.5 PUMPS

3.5.1 System - Head Calculations

Par 1 Applications for approval should be accompanied with system-head calculations and curves for three conditions as follows:

a) C = 120 and low water level in the wet well.

b) C = 130 and median water level over the normal operating range in the wet well.

c) C = 140 and overflow water level in the wet well.

Par 2 Curve (b) should be used to select the pump and motor since this will reflect the normal operating condition. The extreme operating ranges will be given by the intersections of curves (a) and (c) with the selected pump curve. The pump and motor should be able to operate satisfactorily over this full range.

Par 3 Although it is normal to size pumps and motors for the 10-year peak flows, consideration should be given to how the 20-year and ultimate sewage flow requirements can be handled. These operating points should also be shown on the system-head curves.

Par 4 For small diameter forcemains (less than 300 mm (12 in.)), the use of lower "C" factors than listed above should be considered.

3.5.2 <u>Constant Speed vs Variable Speed Pumps</u>

Par 1 In certain instances, such as pumping stations discharging directly to mechanical sewage treatment plants or into other pumping stations, some means of flow pacing may be required. This can be

provided by various means, depending upon the degree of flow pacing necessary. If even minor pump surges would have serious effects, variable speed pumps should be used. If minor surges can be tolerated, two-speed pumps or multiple constant speed pumps can be used.

3.5.3 Ministry of the Environment Specifications

Par 1 A number of specifications have been prepared by the Ministry to assist designers of sewage pumping stations. The following is a list of these specifications:

a) "Standard Specification for Factory-Built Underground Sewage Pumping Stations" MOE Spec. No. 1.
b) "Standard Specification for Diesel Generator Sets" MOE Spec. No. 2
c) "Standard Specification for Submersible Sewage Pumps, Auxiliary Equipment and Controls" MOE Spec. No. 3.
d) "Standard Specification for Dry Pit, Non-Clog Vertical Sewage Pumps" MOE Spec. No. 4.
e) "Standard Specification for Magnetic Flow Meters for Water and Sewage Works" MOE Spec. No. 9.

Par 2 With Provincially funded projects these specifications must be followed, with municipally or privately-financed projects they serve as guidelines only.

3.6 WET WELLS

Par 1 Wet wells should be designed with the following features:

a) The cross-sectional area of the wet well above the benching should be constant for the full depth of the wet well.

b) The wet well should be benched to prevent solids deposition and to allow the solids to be transported into the zone of influence of the pump suctions. The benching should at least be at a 1:1 slope and extend to within D/2 of the edge of the intake flared elbow (where "D" is the diameter of the mouth of the flared elbow.)

c) Access to the wet well should always be from the outside. An access ladder should be provided from the top slab to the service platform, and a separate ladder from the platform to the bottom of the wet well.

d) The opening to the wet well should be no smaller than 600 x 750 mm (24 x 30 in.). The cover should be equipped with a lock. The opening edge should be flush with the vertical wall of the wet well.

e) The opening to the wet well should be on the wall giving access to float controls, bubbler lines, etc.

f) The requirements of the Ministry of Labour must

be satisfied in the design of the wet well (as well as dry well).

g) Wet wells are classified as Class 1, Group D, Division II, Hazardous Location and the requirements of the Ontario Electrical Safety Code, Section 18, must be satisfied for all electrical installations in wet wells, or the equipment must be CSA approved for use in sewage wet wells.

h) A service platform is normally required to allow for equipment servicing and bar screen cleaning (if used).

i) All wet wells should be equipped with a high water level alarm and wherever possible, an emergency overflow should be provided to guard against basement flooding in the event of pumping station failure. Details on the high and normal water levels in the receiving watercourse will be required by the Ministry of the Environment. Backflow and/or shut off valving may be required on the overflow. High water alarms should signal to headquarters manned on a 24-hour basis.

j) All wet wells must be provided with ventilation. Usually natural ventilation will suffice for most pumping stations. This can be achieved through a 100 mm (4 in.) diameter pipe with a gooseneck at the top, extending 900 mm (36 in.)

above the top slab of the wet well. The vent should be equipped with an insect screen. For wet wells up to 7.6 m (25 ft.) deep, one exit vent extending to the bottom surface of the top slab will suffice. For deeper wells, a second ventilator, positioned on the opposite side of the wet well, is recommended to give air circulation. This pipe should extend to within 900 mm (36 in.) of the wet well alarm level.

If the operating authority prefers, a mechanical ventilation system may be used. The ventilating fan should be oriented to blow fresh air into the wet well at a point 900 mm (36 in.) above the alarm level rather than exhaust from the wet well. A separate exit vent, or vents, will be required as described in the paragraph above.

Under no circumstances should wet well vents open into a building or connect with a building ventilation system.

k) Wet well sizing will be influenced by factors such as the volume required for pump cycling; dimensional requirements to avoid turbulence problems; the vertical separation between pump control points; the inlet sewer elevation(s); capacity required between alarm levels and basement flooding and/or overflow elevations; number of, and horizontal spacing between pumps. The minimum size wet well should at least be 2.4 m

(8 ft.) diameter. To avoid septicity problems, however, wet wells should not provide excessive retention times.

For any pumping station, the wet well should be of sufficient size to allow for a minimum of a 10-minute cycle time for each pump. For a 2-pump station, the volume in m^3, between pump start and pump stop should be 0.15 times the pumpage rate of one pump, expressed in L/s. For other numbers of pumps, the required volume depends upon the operating mode of the pumping units.

Float controls should be at least 300 mm (12 in.) vertically and 450 mm (18 in.) horizontally apart and positioned against a wall away from turbulent areas.

To minimize pumping costs and wet well depth, normal high water level (pump start elevation) may be permitted to be above the invert of the inlet sewer(s) provided basement flooding and/or solids deposition will not occur. Where these problems cannot be avoided, the high water level (pump start elevation) should be approximately 300 mm below the invert of the inlet sewer.

Low water level (pump shut-down) should be at least 300 mm (12 in.) or twice the pump suction diameter above the centre line of the pump volute.

The bottom of the wet well should be no more than D/2, nor less than D/3 below the mouth of the

flared intake elbow.

l) Divided wet wells should be considered for all pumping stations with capacities in excess of 100 L/s (1300 igpm).

m) The need for, and the type of screening facilities required for pumping stations varies with the characteristics of the sewage and the requirements of the operating authority. For submersible pumping stations, screening may not be required, but for wet well/dry well stations, it is generally accepted practice to provide screening in the form of a basket screen or a manually or mechanically cleaned bar screen. Although basket screens may be cumbersome to remove and empty, they have the advantage of not requiring entry of operating staff into the wet well for cleaning operations. With basket screens, guide rails should be tubular and similar to submersible pump guide rails. Manually cleaned bar screens should be provided with 38 mm ($1\frac{1}{2}$ in.) clear openings in the inclined (60°) and horizontal bars. The vertical sides should be solid. The minimum width should be 600 mm (24 in.). A drain platform should be provided for screenings.

n) A potable water supply should not be connected into a wet well. If a water source is required for the wet well, it can be provided via a hose connection in the wall of the generator building

or via a yard hydrant. All potable water service lines on a sewage pumping station site must be equipped with a backflow preventor of the reduced pressure zone type (double check valve type not acceptable) and be approved by CSA or manufactured in accordance with AWWA C506 and be installed such as to isolate the sewage pumping station from the distribution main. Refer to Appendix C of the Water Distribution System Guidelines for a more detailed discussion of cross-connection control.

o) In wet well/dry well installations, the air bubbler line (if used) and sump pump discharge should be raised above the overflow elevation, in either the wet or dry well, and should cross between the wells below the frost line.

3.7 PUMP SUCTION LINES

Par 1 Pump suction lines should be designed with the following features:

a) Inlets consisting of 90^{o} short radius down-turned flared elbows;

b) Suction velocities for 20-year, or greater, pumpage requirements, preferably in the low end of the following range - 0.8 to 2.0 m/s (2.6 to 6.6 fps);

c) Flanged wall pipe with water stop collar;

d) Gate valve (flanged);

e) Flanged eccentric reducer.

3.8 PUMP DISCHARGE PIPING

Par 1 Pump discharge piping should be designed with the following features:

a) Velocities, for the 20-year, or greater, pumpage requirements, preferably in the low end of the following range - 0.8 to 4.0 m/s (2.6 to 13 fps);
b) Flanged, concentric increaser;
c) Spacer 150 to 300 mm (6 to 12 in.) long with one flanged end and one grooved end for victaulic coupling;
d) Elbows (as necessary);
e) Check valve (flanged), preferably horizontally placed;
f) Gate valve (flanged)
g) Flanged double branch elbow (for 2-pump station);
h) Riser pipe;
i) Magnetic flow meter (or pump timer for small, constant speed stations).

3.9 DRY WELLS

Par 1 For detailed guidelines reference should be made to the Ministry Specifications mentioned in Section 3.5.3. Some necessary design features are listed below:

a) Mechanical (forced) ventilation must be provided in accordance with the Ministry of Labour requirements.

b) A sump pump must be provided to discharge any water accumulations from the dry well to the wet well. The use of two sump pumps and a dry well flood alarm is recommended practice;

c) Due to the possibility of flooding, it is inadvisable to provide a water service into the dry well;

d) Dehumidification should be provided to protect electrical control equipment from excess moisture;

e) Each pump should be equipped with a time totalizer and provision for manual alteration of the lead pump;

f) A lifting beam complete with permanently attached trolley should be provided directly above the pump/motor assembly at a minimum height of 1.2 m above the motors to facilitate removal of the pump motors.

3.10 FORCEMAINS

Par 1 Forcemains should have the following design features:

a) Velocities should be in the range of 0.8 to 2.5 m/s (2.6 to 8.2 fps), with the lower limit being preferred for the initial phase;

b) The forcemain (and station piping) should be checked for its ability to withstand whatever waterhammer pressures may be experienced. If

necessary, measures such as double-acting air valves at critical forcemain locations, dumping valves on the discharge header, etc. may be required to avoid dangerous waterhammer conditions;

c) Acceptable forcemain materials include asbestos-cement, ductile iron, PE, PVC, steel, concrete, and fiberglass reinforced plastic. See Section 4.0 of the "Guidelines for the Design of Water Distribution Systems" for a discussion of pressure pipe design;

d) Forcemains should be a minimum diameter of 100 mm (4 in.);

e) To allow pumping stations to be by-passed, during emergencies or major modifications, all forcemains should be equipped with a suitably valved connection to permit connection of discharge piping from a portable pump(s). This connection should be located near the pumping station, but on undisturbed ground, away from the excavation zone for the station itself;

f) Air release valves, suitable for use with sewage, should be positioned at all forcemain high points. These should generally be of the low pressure double acting type.

APPENDIX A

Application of MOE Guidelines on Provincially Funded Programs

Par 1 Where a conflict exists between the Ministry of the Environment's guideline and the minimum requirement of a Municipality which is receiving Provincial funding for capital works, the MOE guidelines shall be adhered to, except in cases where the municipal standards have been found to be acceptable to MOE.

Par 2 Alternative materials as listed in Section 4.0 of the guidelines, shall be specified in the tender documents, and prices obtained for such alternatives, regardless of the eventual choice by the Municipality of the material finally used for construction.

Par 3 Direct Provincial grants to Municipalities will only be applicable to normal restoration associated with the construction of the proposed works and any reconstruction or rebuilding of roads, sidewalks, parking areas, etc. are not items which will be eligible for inclusion in the total cost of the project on which subsidy will be based.

a) Design flow allowance for raw industrial land will be 112 m^3/ha.d maximum unless prior arrangements have been made for cost sharing.

b) Minimum sewer grades will be in accordance with Section 2.5.4, except the grades will not be steepened to achieve 0.6 m/s in sewers where the depth of flow at the design Q is less than 0.33.

c) Minimum sewer size will be 200 mm.

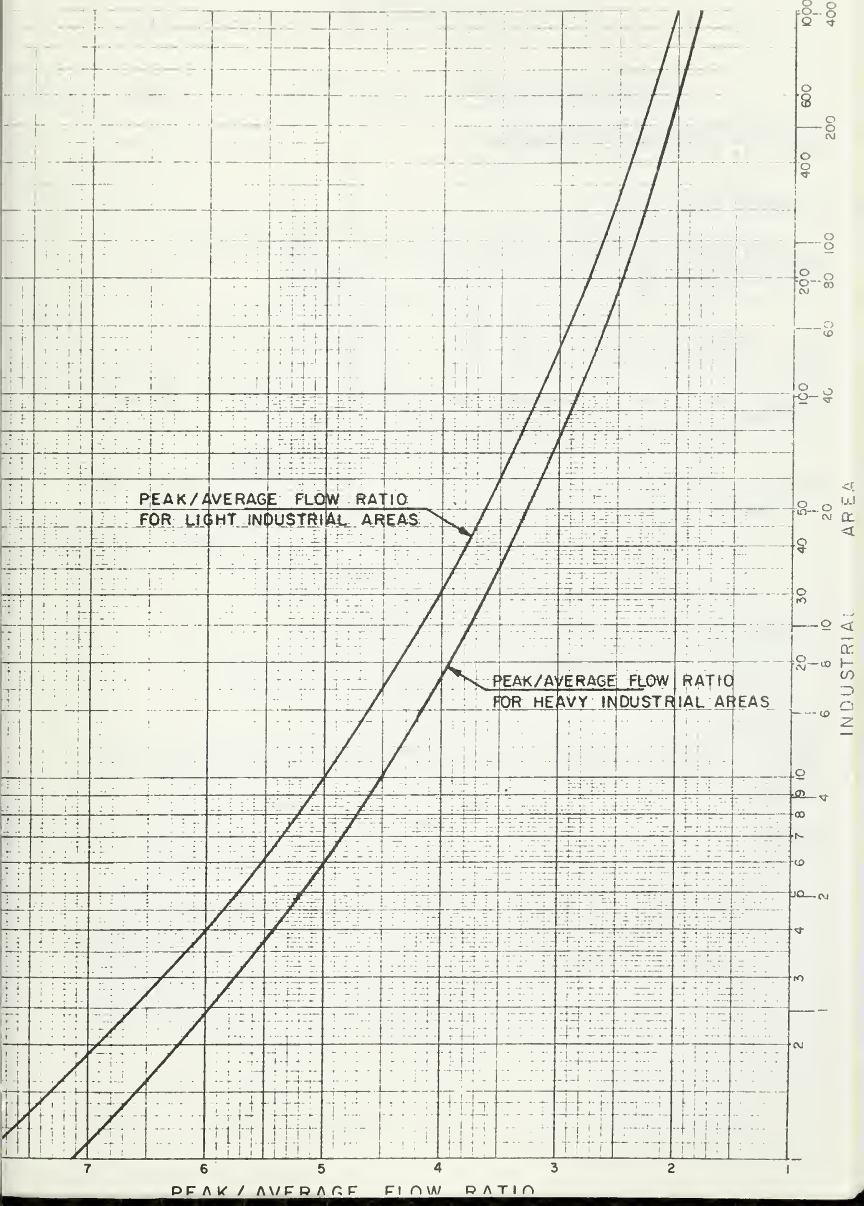
d) Manholes will be in accordance with MOE standard drawings.

e) Service connections will be a minimum of 125 mm for single connections and 150 mm for double connections.

f) Sewage pumping station design and layout will be in accordance with MOE standard specifications as listed on Page 38 of the guidelines and as shown on the MOE standard sketches.

APPENDIX B

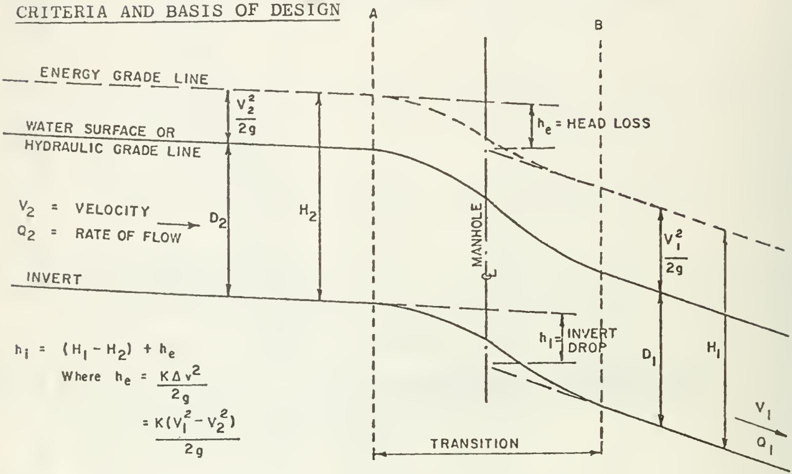
TYPICAL INDUSTRIAL SEWAGE FLOW PEAKING FACTORS



APPENDIX C

HYDRAULIC CALCULATIONS FOR JUNCTION AND TRANSITION MANHOLES

CRITERIA AND BASIS OF DESIGN



$h_i = (H_1 - H_2) + h_e$

Where $h_e = \dfrac{K \Delta v^2}{2g}$

$= \dfrac{K(V_1^2 - V_2^2)}{2g}$

K = 0.1 FOR INCREASING VELOCITY CHANGE

K = 0.2 FOR DECREASING VELOCITY CHANGE

ASSUMPTION

Manhole length is relatively short so that h_i can effectively be taken to be the actual drop in inverts at the extremes of the manhole.

METHOD

1. Each incoming pipe must be analyzed separately together with the outgoing pipe.
2. Employ Hydraulic Elements Chart (shown on last page of Appendix C) for % depth of flow and % velocity.
3. The designer should, wherever possible, restrict the change in velocity to not more than 0.6 m/s (2.0 fps). In special cases, consideration should be given to bellmouth entrances.
4. Complete the hydraulic calculations outlined in the following.

HYDRAULIC CALCULATIONS

FOR JUNCTION AND TRANSITION MANHOLES

Location Manhole No. ....

At ....

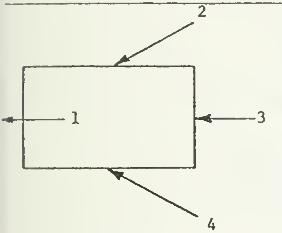
....

Date ....

Designed by: ....

Checked by: ....

Date: ....



PIPE NO.	DIAM.	GRADE %	CAPACITY Q Cap	EXP FLOW Q Act
1				
2				
3				
4				

Pipe No. 1 Q_1 cap =______ Q_1 act = ______ $\dfrac{Q_1 \text{ act}}{Q_1 \text{ cap}}$ = ______

From fig. 1 read Depth of Flow = %

V_1 cap = ______ from above depth of flow and fig. 1 read ratio of V_1 act/V_1 cap = ______

$\therefore$ V_1 act = V_1 cap x $\dfrac{\_\_\_\_\_\%}{100}$ = ______ x $\dfrac{\_\_\_\_\_}{100}$ = ______

H_1 = pipe diameter x % depth + $\dfrac{(V_1 \text{ act})^2}{2g}$ =

______ x ______ + ______ = ______

Pipe No. 2 Q_2 cap = ______ Q_2 act = ______ $\frac{Q_2 \text{ act}}{Q_2 \text{ cap}}$ = ______

From fig. 1 read Depth of Flow = %

V_2 cap = ______ from above depth of flow and

fig. 1 read ratio of V_2 act/V_2 cap = ______

$\therefore V_2 \text{ act} = V_2 \text{ cap} \times \frac{\_\_\_\_\%}{100} = \_\_\_\_ \times \frac{\_\_\_\_}{100} = \_\_\_\_$

H_2 = pipe diameter x % depth + $\frac{(V_2 \text{ act})^2}{2g}$ =

______ x ______ + ______ = ______

Pipe No. 3 Q_3 cap = ______ Q_3 act = ______ $\frac{Q_3 \text{ act}}{Q_3 \text{ cap}}$ = ______

From fig. 1 read Depth of Flow = %

V_3 cap = ______ from above depth of flow and

fig. 1 read ratio of V_3 act/V_3 cap = ______

$\therefore V_3 \text{ act} = V_3 \text{ cap} \times \frac{\_\_\_\_\%}{100} = \_\_\_\_ \times \frac{\_\_\_\_}{100} = \_\_\_\_$

H_3 = pipe diameter x % depth + $\frac{(V_3 \text{ act})^2}{2g}$ =

______ x ______ + ______ = ______

Pipe No. 4 Q_4 cap = ______ Q_4 act = ______ $\frac{Q_4 \text{ act}}{Q_4 \text{ cap}}$

From fig. 1 read Depth of Flow = %

V_4 cap = ______ from above depth of flow and

fig. 1 read ratio of V_4 act/V_4 cap = ______

$\therefore V_4 \text{ act} = V_4 \text{ cap} \times \frac{\_\_\_\_\%}{100} = \_\_\_\_ \times \frac{\_\_\_\_}{100} = \_\_\_\_$

H_4 = pipe diameter x % depth + $\frac{V_4 \text{ act})^2}{2g}$ =

______ x ______ + ______ = ______

HEAD LOSS

$$h_e = \frac{K(V_2^2 - V_1^2)}{2g} \text{ for pipes 1 and 2}$$

Select K = 0.1 or 0.2 as above

For pipes 1 and 2 h_e = _____ (_____ - _____)

= _____

For pipes 1 and 3 h_e = _____ (_____ - _____)

=

For pipes 1 and 4 h_e = _____ (_____ - _____)

=

$\therefore$ for pipes 1 and 2 $h_i = (H_1 - H_2) + h_e$

h_i = _____ - _____ + _____

= _____ drop

for pipes 1 and 3 h_i = _____ - _____ + _____

= _____ drop

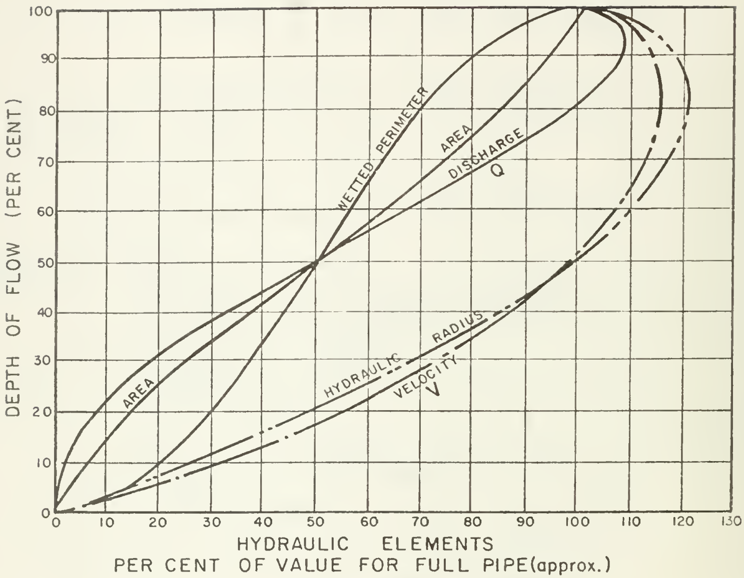
for pipes 1 and 4 h_i = _____ = _____ + _____

= _____ drop

SUMMARY

Take maximum condition of the above three cases as the governing factor which sets the required maximum drop through the manhole.

FIGURE I


100
90
80
70
60
50
40
30
20
10
0
DEPTH OF FLOW (PER CENT)
WETTED PERIMETER
AREA
DISCHARGE
Q
AREA
HYDRAULIC RADIUS
VELOCITY
V
0
10
20
30
40
50
60
70
80
90
100
110
120
130
HYDRAULIC ELEMENTS
PER CENT OF VALUE FOR FULL PIPE(approx.)

SANITARY SEWER DESIGN SHEET

q = average daily per capita flow (____ L/cap d)
I = unit of peak extraneous flow (____ L/ha s)
M peaking factor
Q(p) = peak population flow (L/s)
Q(i) = peak extraneous flow (L/s)
Q(d) = peak design flow

$M = 1 + \frac{14}{4 + P^{0.5}}$ where P = population in 1000's

$Q(p) = \frac{PqM}{86.4}$ (L/s)

$Q(i) = IA$ (L/s) where A = area in hectares

$Q(d) = Q(p) + Q(i)$ (L/s)

LOCATION			INDIVIDUAL		CUMULATIVE		Peaking factor M	Pop flow Q(p) (L/s)	Peak extraneous flow Q(i) (L/s)	Peak design flow Q(d) (L/s)	PROPOSED SEWER						
STREET	FROM	TO	Pop	Area A (hectares)	Pop	Area A (hectares)					Length (m)	Pipe size (mm)	Type of pipe	Grade %	Capacity (L/s) n= ____	Full flow velocity (m/s)	Actual velocity at Q(d)

DESIGN	PROJECT	SHEET Nº
CHECKED		____ of ____
DATE		

APPENDIX E

Proposed Policy for Location of Sewers and Watermains

1. Sewers and watermains located parallel to each other should be constructed in separate trenches maintaining the maximum practical horizontal separation.

2. In cases where it is not practical to maintain separate trenches or the recommended horizontal separation cannot be achieved the Ministry of the Environment may allow deviation from the above.

GUIDELINES

1. GENERAL

Par 1 Ground or surface water may enter an opening in the water distribution system with the occurrence of a negative internal/positive external pressure condition. Ground water may enter the distribution system at leaks or breaks in piping, vacuum-air relief valves, blow-offs, fire hydrants, meter sets, outlets, etc. Water pressure in a part of the system may be reduced to a potentially hazardous level due to shut downs in the system, main breaks, heavy fire demand, high water usage, pumping, storage, or transmission deficiency.

Par 2 The relative location of sewers and watermains (including appurtenances) and types of material used for each system are important considerations in designing a system to minimize the possibility of contaminants entering the water distribution system.

Par 3 The use of, and adherance to, good engineering and construction practice will reduce the potential for health hazard in the event of the occurrence of conditions conducive to ground water flow into the water distribution system.

2. PARALLEL INSTALLATIONS

Par 1 1. Under normal conditions watermains should be laid with at least 2.5 metres horizontal separation from any sewer or sewer manhole; the distance shall be measured from the nearest edges.

a) Under unusual conditions where a significant portion of the construction will be in rock, or where it is anticipated that severe dewatering problems will occur or where congestion with other utilities will prevent a clear horizontal separation of 2.5 metres, a watermain may be laid closer to a sewer, provided that the elevation of the crown of the sewer is at least 0.5 metres below the invert of the watermain. Such separation shall be of in-situ material or compacted backfill.

b) Where this vertical separation cannot be obtained the sewer shall be constructed of materials and with joints that are equivalent to watermain standards of construction and shall be pressure tested to assure water tightness.

c) In rock trenches, facilities should be provided to permit drainage of the trench to minimize the effects of impounding of surface water and/or leakage from sewers in the trench.

3. CROSSINGS

Par 1 1. Under normal conditions watermains shall cross above sewers with sufficient vertical separation to allow for proper bedding and structural support of the watermain and sewer main.

Par 2 2. When it is not possible for the watermain to cross above the sewer, the watermain passing under a sewer shall be protected by providing:

a) A vertical separation of at least 0.5 metres between the invert of the sewer and the crown of the watermain.

b) Adequate structural support for the sewers to prevent excessive deflection of joints and settling.

c) That the length of water pipe shall be centered at the point of crossing so that the joints will be equidistant and as far as possible from the sewer.

4. SERVICE CONNECTIONS

Par 1 Wherever possible the construction practices outlined in this guideline should apply with respect to sewer and water services.

5. TUNNEL CONSTRUCTION

Par 1 If the "tunnel" is of sufficient size to permit a

man to enter the tunnel for the purposes of maintenance, etc., it is permissible to place the sewer and watermain through the tunnel providing the watermain is hung above the sewer.

Par 2 If the tunnel is sized only to carry the pipes, or if the tunnel is subject to flooding, the sewer shall be constructed of materials and with joints that are equivalent to watermain standards of construction and shall be pressure tested to assure water tightness.

6. DESIGN FACTORS

Par 1 When local conditions do not permit the desired spacing of water and sewer lines or other conditions indicate that detailed investigations are warranted, the following factors should be considered in the design of the environment and relative location of water and sewer lines.

Par 2 This list of factors should be considered as a guide and not all inclusive:

a) Materials, types of joints, and identification for water and sewage pipes;

b) Soil conditions, e.g. in-situ soil and backfilling materials and compaction techniques;

c) Service and branch connections into the watermain and sewer lines;

d) Compensating variations in the horizontal and vertical separations;

e) Space for repair and alterations of water and sewer pipes;

f) Off-setting of pipes around manholes;

g) Location of ground-water table and trench drainage techniques;

h) Other sanitary facilities such as septic tanks and tile fields, etc.

7. VALVE, AIR RELIEF, METER AND BLOW-OFF CHAMBERS

Par 1 a) Chambers or pits containing valves, blow-offs, meters or other such appurtenances to a water distribution system shall not be connected directly to any storm or sanitary sewer, nor shall blow-offs or air-relief valves be connected directly to any sewer.

b) Such chambers or pits shall be drained to the surface of the ground where they are not subject to flooding by surface water; to absorption pits underground or to a sump within the chamber where ground water level is above the chamber floor.

8. RESERVOIRS BELOW NORMAL GROUND SURFACE

Par 1 Sewers, drains, and similar sources of contamination should be kept at least 15 m (50 ft.) from the

reservoir. Mechanical-jointed water pipes, pressure tested in place to 350 kPa (50 psi) without leakage, may be used for gravity sewers at lesser separations.

9. UNACCEPTABLE INSTALLATIONS

Par 1 No watermain or service line shall pass through or come into contact with any part of a sewer or sewer manhole.

APPENDIX F

MINISTRY OF THE ENVIRONMENT

POLICY AND GUIDELINES TO GOVERN THE USE OF PLASTIC PIPE FOR BURIED GRAVITY-FLOW SEWERS

(The following letters, policy and guidelines outline the requirements for the use of plastic pipe for sewers on Ministry of the Environment Projects)

Consulting Engineers on Ministry of the Environment Projects:

Gentlemen:

RE: PLASTIC PIPE FOR BURIED GRAVITY FLOW SEWERS

Under cover of a letter dated November 26, 1975, Mr. K. E. Symons, Director, Pollution Control Branch, distributed this Ministry's policy and support guidelines to govern the use of plastic pipe for buried gravity-flow sewers. In Item 8 of the Guidelines for the Design and Installation of a Plastic Pipe for Buried Gravity-Flow Sewers, it is indicated that the Ministry would provide its Consulting Engineers with more specific requirements regarding the use of plastic pipes on Ministry financed programmes.

This supplementary information is as follows:

1. The design calculations for plastic gravity flow sewers as carried out by the Ministry's Consulting Engineer, setting out all design criteria and assumptions, shall be submitted to the Ministry. Any checking of such calculations for the Ministry shall be done by the Ministry's Technical Services Branch.

2. The specifications covering installation and field testing of gravity-flow sewers as prepared by the Ministry's Consulting Engineer shall take into account the requirements set out for the Ministry's "APPENDIX 1 TO STANDARD SPECIFICATION #11 COVERING CONCRETE SEWER PIPE - GUIDELINES FOR REQUIREMENTS FOR INSTALLATION AND FIELD TESTING". The said "GUIDELINES" are applicable to sewer pipes of all materials, not

only concrete, but are to be considered as minimum requirements. In preparing specifications for a specific contract, the Consulting Engineer shall add such further provisions as are necessary or desirable for the particular contract. Copies of the Ministry's "Policy and Guidelines to Govern the Use of Plastic Pipe for Buried Gravity-Flow Sewers" and "Appendix 1 to Standard Specification #11 Covering Concrete Sewer Pipe" may be obtained form either the Project Co-ordination Branch or the Technical Services Branch.

Yours very truly,

(originally signed by
Mr. T. W. Cross)

T. W. Cross, P. Eng.
Director
Technical Services Branch

BJC/cc

ONTARIO MINISTRY OF THE ENVIRONMENT

135 St. Clair Avenue West
Toronto, Ontario
M4V 1P5

TO WHOM IT MAY CONCERN:

RE: POLICY AND GUIDELINES TO GOVERN THE USE OF PLASTIC PIPE FOR BURIED, GRAVITY-FLOW SEWERS

Since the implementation of the above-mentioned policy and support guidelines about a year ago, it has been called to our attention, by the consultants and plastic pipe manufacturers, that the "earth loading" term (used in modified Spangler Equation) defined in its present form in our Policy, may be subject to misinterpretation. The "earth loading" term represents trench loading which is given merely as an example of the many possible loading conditions. If it is applied incorrectly for other loading conditions, serious errors will result in the pipe design.

In addition, we have also noted that an update of the minimum acceptable value of the pipe stiffness ($F/\Delta Y$) as well as the test procedure on pipe deflection after installation, as described in our Policy, becomes necessary in order to conform with the most current field practice.

Accordingly, the Plastic Pipe Policy and Guidelines have now been revised, and I am pleased to be able to provide you with a copy of the revised edition.

Further information can be obtained from Dr. P. Seto, Head, Municipal Sewage Unit, Municipal and Private Section, Pollution Control Branch, at the above address, telephone: (416) 965-6967.

Yours very truly,

(Originally signed by
Mr. K. E. Symons)

K. E. Symons, Director
Pollution Control Branch

Encl.

MINISTRY OF THE ENVIRONMENT

POLICY AND GUIDELINES
TO GOVERN THE USE OF
PLASTIC PIPE
FOR
BURIED, GRAVITY-FLOW SEWERS

A. POLICY

B. GUIDELINES

POLLUTION CONTROL BRANCH

Revised March 7, 1977

A. POLICY TO GOVERN THE USE OF PLASTIC PIPE FOR BURIED, GRAVITY-FLOW SEWERS

Par 1 The Ministry will allow the use of plastic pipe for buried, gravity-flow sewer installations.

Par 2 Plastic pipe for use in such installations will be selected using the modified Spangler equation for flexible pipe (use Imperial units in the following equation).

$$x = \frac{D.K.W._c}{0.149\ F/\Delta Y + 0.061\ E'}$$

(maximum allowable deflection = 5% of internal diameter)

Reference: ASTM D2412

Par 3 In the absence of conclusive evidence of local conditions to the contrary a bedding factor (K) of 0.110 and a soil modulus (E') of 1379 kPa (200 psi) shall be used for calculation of pipe deflection.

Par 4 In any plastic sewer pipe installation the Contractor shall be required to pass through the pipe a ball, plug, or other suitably designed device of not less than 95% of the minimum permissible internal diameter of the pipe as defined in the Standard to which the pipe is made. The ball, plug or device shall be pulled manually through the pipe not sooner than 24 hours after the completion of

backfilling. Failure of this test renders the installation unacceptable.

Par 5 All plastic pipe used for buried gravity-flow sewers shall be capable of withstanding an impact of 50 foot-pounds at a temperature of -20°C under standard test conditions.

(Note: Tests may be conducted at 0°C and the results extrapolated to -20°C)

B. GUIDELINES FOR THE DESIGN AND INSTALLATION OF PLASTIC PIPE FOR BURIED, GRAVITY-FLOW SEWERS

Par 1 Plastic pipe is, by definition, a flexible material and, therefore, the basic engineering design criteria governing its use for buried, gravity-flow sewers will be based upon ring deflection rather than upon stress in the side walls as is the case for rigid pipe. In view of the large variety of plastic pipes available, the Ministry of the Environment has chosen not to classify the detailed engineering specifications (e.g. pipe connections practice, fittings and gaskets requirements, trenching and bedding condition, etc.) for individual types of plastic pipes; instead the design of the sewer system, including the selection of pipe class, must be carried out in accordance with recognized and accepted engineering practice and the recommendations of the pipe manufacturer. It is understood that design calculations may be checked by the Ministry.

Par 2 In addition, the following specific guidelines shall be adhered to:

1. Sewer system shall be designed on the basis of a Friction Factor of n=0.013 for the Manning formula.
2. Pipe with F/ΔY less than 1.83 kg/cm/cm (26 lbs./in./in.) shall not be used.

3. Deflection lag factor (D) of 1.5 shall be used.
4. The minimum size for laterals connecting the street sewers to sewers on private property shall be 100 mm (4 in.) in diameter.
5. Laterals shall be designed for worst conditions, i.e. E' = 1379 kPa (200 psi), K=0.110.
6. The manufacturer shall supply to its customers, as required, plastic specials and fittings compatible with the straight plastic pipe supplied and conforming to the design requirements for the said pipe. Tees for service connections shall be available to permit connection to other generally accepted pipe materials such as concrete, asbestos cement and vitrified.
7. Actual installation of pipe shall conform to accepted engineering practice and manufacturer's recommendations. The installation shall be closely inspected.
8. For Ministry financed and/or subsidized projects, the Ministry will issue to its consulting engineers more specific requirements, supplementary to the foregoing, including provisions to be incorporated in the contract specifications.

REVISED MARCH 7, 1977

APPENDIX G

Bibliography

1. "Guidelines for Energy Conservation in the Design of Sewage Systems and Treatment Facilities in the Province of Ontario", Project Co-ordination Branch, Ministry of the Environment, 135 St. Clair Avenue West, Suite 100, Toronto, Ontario. M4V 1P5

2. "Design Manual for Sewers and Watermains" Municipal Engineers Association and the Ontario Ministry of the Environment, W. J. Warwick, P. Eng., Course Director, Sewer and Watermain Design Course, Engineering Branch, Borough of Scarborough, 150 Borough Drive, Scarborough, Ontario. M1P 4N7

3. "Design and Construction of Sanitary and Storm Sewers", WPCF Manual of Practice No. 9, Water Pollution Control Federation, 3900 Wisconsin Avenue, Washington, D.C., U.S.A. 20016

4. "Wastewater Systems - Pipes and Piping", Manual of Practice No. 3, Water and Wastes Engineering.

5. "Concrete Pipe Design Manual", American Concrete Pipe Association, 1501 Wilson Blvd., Arlington, Virginia, U.S.A. 22209

6. "Handbook of Steel Drainage and Highway Construction Products", American Iron and Steel Institute, 150 East

42nd Street, New York, New York, U.S.A. 10017

7. "Plastic Pipe in Sanitary Engineering" Lars-Eric Janson, Celanese Piping Systems, 4300 Cemetary Road, Hilliard, Ohio, U.S.A. 43026

8. ASTM Standards, American Society for Testing and Materials, Philadelphia, Pennsylvania, U.S.A.

9. CSA Standards, Canadian Standards Association, 178 Rexdale Blvd., Rexdale, Ontario. M9W 1R2

10. CGSB Standards, Canadian Government Specification Board Supply and Services Canada, Place Du Portage, Phase III, 11 Laurier Street, Hull, Quebec. K1A 0S5

11. Standard Specification: MOE Spec. No. 1, Factory-built Underground Sewage Pumping Stations; MOE Spec No. 2 Diesel Generator Sets; MOE Spec. No. 3, Submersible Sewage Pumps, Auxiliary Equipment and Controls; MOE Spec. No. 4, Dry Pit, Non-Clog, Vertical Sewage Pumps; MOE Spec No. 9, Magnetic Flow Meters for Water and Sewage Works; Project Co-ordination Branch, Ontario Ministry of the Environment, Suite 100, 135 St. Clair Avenue West, Toronto, Ontario. M4V 1P5

12. "Process Design Manual for Sulphide Control in Sanitary Sewerage Systems", U. S. Environmental Protection Agency, Technology Transfer, October 1974.

GUIDELINES FOR THE DESIGN

OF

WATER DISTRIBUTION SYSTEMS

MAY 1979

The Honourable
Harry C. Parrott, D.D.S.,
Minister

Graham W. S. Scott,
Deputy Minister

GUIDELINES FOR THE DESIGN

OF

WATER DISTRIBUTION SYSTEMS

MAY 1979

MUNICIPAL AND PRIVATE APPROVALS SECTION
ENVIRONMENTAL APPROVALS BRANCH

MINISTRY
OF THE
ENVIRONMENT

ACKNOWLEDGEMENTS

This design guideline has been prepared with the assistance of the consulting firm of Simcoe Engineering Limited, Pickering, Ontario. The draft guideline, prepared by the consultant, underwent an initial review by a committee including representatives from District, Metropolitan, and Regional Municipalities. The members of this committee were as follows:

G. L. Wilson
District Municipality of Muskoka

R. G. Ferguson
Municipality of Metropolitan Toronto

W. A. Evans
Regional Municipality of Durham

R. W. Healey
Regional Municipality of Haldimand-Norfolk

H. H. Cripps
Regional Municipality of Halton

P. Marko
Regional Municipality of Hamilton-Wentworth

G. Woodburn
Regional Municipality of Niagara

W. L. Keay
Regional Municipality of Ottawa-Carleton

W. J. Anderson
Regional Municipality of Peel

D. K. Partington
Regional Municipality of Sudbury

W. R. Pyatt
Regional Municipality of Waterloo

W. E. Bando
Regional Municipality of York

J. R. McMurray
Ontario Ministry of the Environment

N. Borodczak
Ontario Ministry of the Environment

B. C. Cooper
Ontario Ministry of the Environment

D. D. B. Cane
Simcoe Engineering Limited

Following this initial review, revisions were made and the document underwent a final review by committees consisting of representatives from the local municipalities within the various District, Metropolitan, and Regional Municipalities. The present form of the guideline includes changes suggested by these latter committees.

TABLE OF CONTENTS

Table of Contents - 2

1.0 INTRODUCTION

Par 1 This edition of guidelines has been prepared as a revision to the previous issue No. 2 dated June, 1975.

Par 2 These guidelines are primarily intended to outline minimum acceptance levels of servicing to assist consulting engineers, municipal engineering staff, and other designers in the preparation of water distribution system designs that will meet the approval requirements of the Ministry of the Environment. It should be noted that other approval authorities, such as the municipality in which the works will be constructed, may have servicing standards that exceed the requirements of these guidelines. The designer should, therefore, ensure that he is aware of the requirements of all other approving authorities prior to submitting designs for approval.

Par 3 Although some aspects of the guidelines relate only to municipal services, the guidelines are meant to apply where applicable to other systems such as mobile home parks, condominium developments, etc. which also require Ministry of the Environment approval under the Ontario Water Resources Act.

Par 4 To allow the guidelines to be more simply modified in future and to permit faster reference by the

users to specific paragraphs of the text, the guidelines have been broken down into numbered sections and paragraphs as shown along the left hand margin of each page.

Par 5 As a final point, it must be emphasized that this document contains design guidelines. These should not be confused with standards or regulations which must be absolutely complied with in order to obtain approval. It is not the intention of the Ministry of the Environment to stifle innovation. Whenever a designer can demonstrate that environmental and/or health concerns can be safeguarded by alternative approaches, such methods will be considered for approval.

2.0 HYDRAULIC DESIGN

2.1 DESIGN WATER DEMANDS

Par 1 Water supply systems should be designed to satisfy the greater of either of the following demands:

a) Maximum day plus fire flow

b) Peak rate (maximum hourly demand)

Par 2 The maximum day demand is the average usage rate on the maximum day. The fire flow demand will vary with the size of the municipality (chance of multiple fires at any time) and the nature of development (type of construction materials, building height and area, and density of development). The peak rate demand is the short-term demand placed upon the system by usages other than fire fighting. The peak rate demand is usually taken as the average water usage over the maximum hour.

Par 3 Wherever possible, peaking factors based on usage records for the water supply system should be used, but when such records do not exist or are unreliable, factors such as those given in Appendix A may be used.

2.1.1 Unit Consumption Rates

2.1.1.1 Domestic Water Demands

Par 1 Domestic water demands will vary greatly from

municipality to municipality. Depending upon such factors as presence of service metering, lawn-watering practices, water quality, leakage, etc., average daily per capita consumption rates can vary from less than 180 litres (40 gallons) to more than 450 litres (100 gallons).

Par 2 For design purposes, existing reliable records for average, maximum day and peak rates should be used wherever possible. Otherwise, average daily per capita water demands of 270 to 450 litres (60 to 100 gallons) are recommended. Minimum rate, maximum day and peak rate factors for large systems should be in accordance with the values shown in Appendix A.

Par 3 For small residential developments of less than 500 persons, a peak domestic demand of 0.076 to 0.23 L/s (1 to 3 gpm) per dwelling unit should be used for design. Demands as high as 0.45 L/s (6 gpm) per lot have been experienced in estate-type subdivisions during lawn watering periods.

2.1.1.2 Commercial and Institutional Water Demands

Par 1 The water demands for commercial and institutional establishments vary greatly with the type of water-using facilities present in the development, the population using the facilities, the presence of metering, etc.

Par 2 In general, the method to use to estimate water consumption for large commercial areas is to calculate a population equivalent for the area covered by the development, then calculate the water demands on the same basis as discussed in the previous section. A population equivalent of 90 persons per hectare (36 ppa) is often used.

Par 3 For individual commercial and institutional uses, the following unit demands are commonly used. Where a range is stated, the lower figure is a minimum requirement.

	Water Usage (Avg. Daily)
Shopping centres	- 2500-5000 L/1000 m^2.day (based on total floor area) (50-100 gpd/1000 ft^2)
Hospitals	- 900-1800 L/bed.day (200-400 gpd/bed)
Schools	- 70-140 L/student.day (15 to 30 gpd/student)
Campgrounds	- 225-570 L/campsite.day (50 to 125 gpd/campsite)

Par 4 When using the above unit demands, maximum day and peak rate factors must be developed. For establishments in operation for only a portion of the day, such as schools, shopping plazas, etc., the water usage should also be factored accordingly. For instance, with schools operating for 8 hours per day, the water usage rate will be at an average rate of say 70 L/student.day x $\frac{24}{8}$ or

210 L/student.day (45 gpd/student) over the 8-hour period of operation. The water usage will drop to residual usage rates during the remainder of the day. Schools generally do not exhibit large maximum day to average day ratios and a factor of 1.5 will generally cover this variation. For estimation of peak demand rates, an assessment of the water using fixtures is generally necessary and a fixture-unit approach is often used.

Par 5 The peak water usage rates in campgrounds will vary with the type of facilities provided (showers, flush toilets, clothes washers, etc.) and the ratio of these facilities to the number of campsites. A peak rate factor of 4 will generally be adequate, however, and this factor should be applied to the average expected water usage at full occupancy of the campsite.

2.1.1.3 Industrial Water Demands

Par 1 Industrial water demands are normally expressed in terms of water requirements per gross hectare of industrial development. These demands will vary greatly with the type of industry, but common allowances for industrial areas range from 35 m^3/gross hectare.day (3000 gpad) for light industry to 55 m^3/gross hectare.day (5000 gpad) for heavy industry. These are average daily demands. Peak usage rates

will generally be 2 to 4 times the average usage rate.

2.1.1.4 Fire Demands

Par 1 The level of fire protection to be provided by a municipally-owned water supply system is the decision of the municipality. In general, the minimum fire flow, as recognized by various fire underwriting groups is 30 L/s (400 gpm) and to receive credit, the water system must be simultaneously capable of satisfying the maximum day demand.

Par 2 To estimate the fire flow requirements for a particular structure or area of a municipality, the designer should refer to a guide such as, "Water Supply for Public Fire Protection - A Guide to Recommended Practice, 1977", prepared by Public Fire Protection Survey Services, Insurers' Advisory Organization, 180 Dundas Street West, Toronto, Ontario.

2.2 DESIGN PERIOD

Par 1 A 20-year design period is most frequently used for water supply systems. Water distribution systems have useful life expectancies well in

excess of 20 years, however, and if it is possible from a financial point of view, longer design periods may be used. Shorter design periods may be acceptable where works are strictly short-term and will undergo replacement in the foreseeable future.

2.3 SYSTEM PRESSURES

2.3.1 Maximum and Minimum Operating Pressures

Par 1 It is generally accepted practice to design water supply and distribution systems such that the normal operating pressure ranges between 350 kPa and 550 kPa (50 to 80 psi) under a condition of maximum daily flow.

Par 2 The maximum pressures in the distribution system should, in general, not exceed 700 kPa (100 psi) to avoid damage to household hot water tanks, rapid wear of tap washers, unnecessary energy consumption, etc. Where localized areas must have pressures above this level, the homes affected should be provided with individual pressure-reducing valves on their services.

Par 3 The distribution system should be sized so that under maximum hourly demand, the pressures do not fall below 275 kPa (40 psi). Under conditions of simultaneous maximum day and fire flow demands,

the pressure should not drop below 140 kPa (20 psi).

2.3.2 Transient Pressures

Par 1 The distribution piping system must be designed to withstand the maximum operating pressure <u>plus</u> the transient pressures to which it will be subjected. Transient pressures are caused by rapid valve operation, pump start-up and shut-down, power failure, etc. Wherever possible, the design of pumping systems should be such that surges caused by pumping station operations are minimized.

Par 2 As a <u>minimum</u> allowance in the distribution system, it is recommended that the pipe strength be such that it can withstand the maximum operating pressure <u>plus</u> the pressure surge that would be created by instantaneous stoppage of a water column moving at 0.6 m/s (2 fps). The pressure created by such an event will vary depending upon the diameter, wall thickness and material of pipe used in the distribution system.

Par 3 When calculating transient pressures for flexible pipe materials, the designer is cautioned that celerity values given in texts, manufacturer's catalogues and other sources of information are usually for the unrestrained condition. When buried,

such pipe materials will exhibit higher effective celerity values and correspondingly higher transient pressures. Celerity values utilized in transient analyses should be increased for such pipe materials for buried conditions and a rule of thumb is to use twice the value calculated from the celerity equation. The Ministry is currently researching this matter and further guidance will be provided when available.

2.4 FRICTION FACTORS

Par 1 It is recommended that the following "C" valves be used for the design of water distribution systems, regardless of material:

Diameter	C-Factor
150 mm (6 in.)	100
200 & 250 mm (8 & 10 in.)	110
300 to 600 mm (12 to 24 in.)	120
Over 600 mm (Over 24 in.)	130

Par 2 The above C-factors are intended to represent those which would be experienced in the long term. In calculating maximum velocities for transient pressure estimations, or for checking pump motor sizes for runout conditions, it is recommended that a C-factor of 140 be used to allow for new pipe conditions.

Par 3 In evaluating existing systems for expansion, the C-factors should be determined by actual field tests, wherever possible.

2.5 DESIGN CALCULATIONS

Par 1 Design calculations in support of the sizing of minor extensions to water distribution systems will often not be required where minimum pipe size requirements have dictated the sizing. Where new systems, or major extensions are proposed, design calculations demonstrating the adequacy of the system should accompany the application.

Par 2 When an existing distribution system which has, or is suspected to have pressure problems, is proposed to be extended or modified, design calculations will be required to demonstrate the acceptability of the proposed works.

Par 3 If a computer analysis has been carried out on the proposed system, the results of that analysis should be noted on a general plan of the system together with an indication of the conditions imposed in the program.

2.6 MINIMUM PIPE SIZES

Par 1 The minimum size of watermains should be 150 mm (6 in.), inside diameter, except for the following

cases:

a) Watermains in systems not required to carry fire flows.

b) Beyond the last hydrant on cul-de-sacs. In this case, pipe sizes from 50 mm (2 in.) down to 25 mm (1 in.) diameter may be used.

Par 2 In all the above cases, hydraulic calculations should be submitted to demonstrate that the proposed pipe sizes are sufficient to sustain at least the minimum pressures discussed in Section 2.3.1. When the inside diameter of the pipe is less than the normal size, the actual inside diameter should be used in the hydraulic calculations.

Par 3 For water service connections, the minimum pipe size required is 20 mm (3/4 in.) inside diameter.

3.0 SYSTEM LAYOUT

3.1 GRID DESIGN

Par 1 Wherever possible, water distribution system layouts should be designed to eliminate dead-end sections. Where dead-end mains cannot be avoided, they should be provided with a fire hydrant, blow-off or other acceptable measures taken to prevent problems associated with stagnation.

3.2 VALVE PLACEMENT

Par 1 In grid patterns, intersecting watermains should be equipped with shut-off valves, as follows, to minimize disruption during repairs:

	No. of Valves
'T' intersection	at least 2
Cross intersection	at least 3

Par 2 Air release valves should be placed at all significant high points of the system. Where the need for an automatic air release valve is uncertain, a manual air release valve or hydrant can be initially installed and later replaced with an automatic valve, if significant air accumulations are found.

Par 3 With large diameter mains, drain valves positioned at low points may also be required to permit main repairs. Small diameter watermains can generally be

drained through hydrants by using compressed air and/or pumping.

3.3 HYDRANT REQUIREMENTS

Par 1 Being a factor in the level of fire protection to be provided, the provision, spacing and location of fire hydrants is largely the decision of the municipality. The designer should, therefore, acquaint himself with the requirements of the municipality involved.

Par 2 The required hydrant spacing decreases as the fire flow requirement increases. Hydrants must, therefore, be placed much closer together in high risk areas, such as downtown core areas, than in residential areas with detached homes.

Par 3 In residential areas, the line spacing for hydrants is normally recommended to be 120-150 m (400-500 ft.). For a more detailed discussion of hydrant spacing requirements reference should be made to "Water Supply for Public Fire Protection - A Guide to Recommended Practice, 1977".

Par 4 Fire hydrants should only be installed on watermains capable of supplying fire flow requirements. The hydrant leads should be 150 mm (6 in.) diameter pipe.

Par 5 To allow for hydrant maintenance and repair with a

minimum of disruption, it is preferred that all hydrant leads be valved to allow for ease of maintenance.

3.4 DEPTH OF COVER

Par 1 With the exception of those watermains which will be taken out of service and drained in winter, the minimum depth of cover for watermains and service connections should not be less than the depth of frost penetration.

Par 2 As a general guide, the depths of frost penetration within the road allowance for areas of Ontario are as follows:

	Frost Penetration
Southwestern Region	1.5 to 1.8 m (5-6 ft.)
West Central Region	1.7 to 2.0 m ($5\frac{1}{2}$-$6\frac{1}{2}$ ft.)
Central Region	1.7 to 2.0 m ($5\frac{1}{2}$-$6\frac{1}{2}$ ft.)
Southeastern Region	1.7 to 2.1 m ($5\frac{1}{2}$-7 ft.)
Northeastern Region	1.8 to 2.4 m (6-8 ft.)
Northwestern Region	2.1 to 2.6 m (7-$8\frac{1}{2}$ ft.)

Par 3 For any particular location, the depth of frost penetration may differ from the above ranges and reference should either be made to local records, data available from the Atmospheric Environment Branch of Environment Canada, or the Ministry of Transportation and Communications publication "Frost

Depth Penetrations/Ontario 1970-74".

Par 4 Large diameter watermains, over 300 mm (12 in.) without service connections may be installed at such an elevation that the frost-free depth corresponds with the spring line of the pipe rather than the crown.

Par 5 If for economic or practical reasons it is impossible to install watermains in the natural frost-free zone, consideration may be given to reduced cover installations provided the design method ensures that the watermain will not freeze or be damaged by heaving or increased trench loads caused by frost penetration.

Par 6 Recent studies have shown that the penetration of frost into the ground causes increases in the earth load on buried pipes. These studies indicated that earth loads roughly doubled despite the fact that the frost penetration did not reach the tops of the pipes. The earth loadings prior to frost penetration were approximately equivalent to calculated prism loads. In these experiments, it is interesting to note that the loading increased to double the normal earth load as the frost penetration increased, but the closest that the frost layer came to the pipes was 0.22 m (0.75 ft.). It is, therefore, possible that higher loadings would occur if the

frost penetrated closer to the pipe.

Par 7 These increased external loads caused by frost may cause beam breaks in the pipe when bedding is non-uniform. This points to the need for proper attention to the installation of the pipe bedding. It also suggests that great care must be taken in the selection of pipe materials, pipe classes and bedding types.

Par 8 Although various insulation and heating techniques are available, the designer is cautioned to consider the long-term effects and economics of such an approach. Reference should be made to Ministry of the Environment research papers "Design of Buried Pipelines in Cold Climates" and "Temperature Monitoring of an Insulated Watermain".

3.5 CROSS-CONNECTION CONTROL AND SPACIAL SEPARATION OF WATER AND SEWAGE WORKS

Par 1 Precautions must be taken in the design of water distribution and plumbing systems to preclude the entrance of contaminating materials into the water supply.

Par 2 Such contaminants can enter water supply systems from various sources such as cooling water systems, pump seal systems, industrial process piping, groundwater, etc. To control contamination from other

non-potable piped systems, cross-connection control measures are necessary. To prevent or minimize the entrance of dangerous contaminants into the water supply from groundwater sources, certain precautions must be taken with the relative location of sewage and water systems.

Par 3 The Ministry of the Environment has developed interim policies and guidelines covering cross connection control and the location of sewers and watermains. These interim policies and guidelines are contained in Appendix C.

Par 4 For more information on cross connection control equipment, reference should be made to CSA Standard B64.0, "Definitions, General Requirements and Test Methods for Vacuum Breakers and Backflow Preventers".

4.0 PIPE DESIGN

4.1 ALTERNATE PIPE MATERIALS

Par 1 Acceptable alternate materials for watermains include ductile-iron (cement-lined), asbestos cement, reinforced concrete, polyethylene, polyvinyl chloride, cement lined-cement coated steel, and fiberglass reinforced plastic. Pipe selected shall have been manufactured in conformity with the latest standards issued by the American Water Works Association, the Canadian Standards Association, or the Canadian Government Specification Board. In the absence of such standards, pipe manufactured in accordance with certain commercial standards, if acceptable to the Ministry of the Environment, may be selected. See Appendix B for MOE policy on pipe materials used with Provincially funded projects.

Par 2 In selecting a pipe material, the designer should consider the following factors:

a) Costs (capital, operating, maintenance and other costs);
b) Trench foundation conditions;
c) Location;
d) Soil corrosivity;
e) Potable water corrosivity;
f) Available labour skills.

4.2 PIPE STRENGTH

Par 1 Section 2.3.1. and 2.3.2 discussed the operating and transient pressures which are experienced in distribution systems. Buried watermains are also subjected to external loads imposed by the trench backfill, frost loading, and superimposed loads (either static or dynamic, or both). The watermain pipe selected for a particular application must be able to withstand with an adequate margin of safety all the combinations of loading conditions to which it is likely to be exposed.

Par 2 Pipe strength designations and the methods for selecting the required pipe strength vary with the types of materials used for watermains. For a thorough understanding of this subject, it will be necessary for the designer to evaluate the pipe supplier information and consult such references as the pertinent ANSI, AWWA, and CSA Standards and Design Manuals. A general discussion of the design approach used with some of the pipe materials is outlined in the following subsections.

4.2.1 Ductile-Iron Pipe

Par 1 Ductile-iron pipe to be used for watermains should be manufactured in accordance with ANSI A21.51 (AWWA C151) with the cement lining applied in accordance with ANSI A21.4 (AWWA C104). For pipe

manufactured to these standards, the design method and design stresses used to determine the thickness of pipe are covered in Standard ANSI A21.50 (AWWA C150).

Par 2 The wall thickness requirement is determined by separately considering trench load/laying condition and internal pressure. To the greater of the two thickness requirements is then added allowances for corrosion and casting tolerances. The thickness class (Class 50, 51, 52, etc.) is then selected. It should be noted that the design tables assume a transient pressure of 700 kPa (100 psi) and the design pressure is the sum of working pressure and transient pressure times a safety factor of two. If transient pressures greater than 700 kPa (100 psi) are anticipated the thickness requirement for internal pressure must be calculated by the equations provided and Table 50.13 should not be used.

4.2.2 Asbestos-Cement Pipe

Par 1 Asbestos-cement pipe to be used for watermains should be manufactured in accordance with AWWA C400. The pipe design procedures should be in accordance with AWWA C401 (formerly AWWA H2). It should also be noted that installation procedures for asbestos-cement pipe are outlined in AWWA C603.

Par 2 The pipe class selection curves contained in AWWA C401 are based on the combined-loading theory developed by W. J. Schlick. Tests of asbestos-cement pipe under various combinations of internal pressure and external load indicate that the point of pipe fracture follows a parabolic curve. With increasing external loading, asbestos-cement pipe will fail at progressively lower internal pressures.

Par 3 The class rating of the pipe (100, 150, 200, or 300) corresponds to the suggested maximum internal operating pressure in psi which should be used for design when the pipe is laid at 1.5 m (5 ft.) depth of cover, with a trench width equal to I.D. plus 0.6 m (2 ft.), a bedding condition of Class C and a soil density of 1920 kg/m^3 (120 lb./ft^3). With higher external loadings caused by different trench conditions than above, the design operating pressure of the pipe will decrease. The curves provided in AWWA C401 will allow the designer to select the proper pipe class for a wide range of trench and operating conditions.

Par 4 The design curves incorporate safety factors of 4.0 for operating pressures and 2.5 for external loads. Ordinary transient (surge) pressures are allowed for in the safety factor of 4.0. Exceptionally high surge pressures should be calculated and allowed for separately.

Par 5 For municipal water supply systems, a minimum of Class 150 asbestos-cement pipe is recommended by the Ministry of the Environment. For non-municipal type systems where operating pressures in the order of 700 kPa (100 psi) are not anticipated, Class 100 pipe may be used if operating and/or transient pressures and external loading conditions permit.

4.2.3 Reinforced Concrete Pipe

Par 1 Reinforced concrete watermains should be manufactured in accordance with the appropriate AWWA specification for the type of pipe required, as follows:

- REINFORCED CONCRETE PRESSURE PIPE
  STEEL CYLINDER TYPE - AWWA C300
- PRE-STRESSED CONCRETE PRESSURE PIPE
  STEEL CYLINDER TYPE - AWWA C301
- REINFORCED CONCRETE PRESSURE PIPE
  NON-CYLINDER TYPE - AWWA C302
- PRETENSIONED CONCRETE PRESSURE PIPE
  STEEL CYLINDER TYPE - AWWA C303

Par 2 With concrete pipe, the user does not have available the convenient selection curves in the AWWA specifications as are provided for ductile iron or asbestos cement pipe. The design methods are, however, outlined and they should be followed closely. To avoid errors in pipe selection, the

designer should provide the pipe manufacturer with the information suggested in the appropriate AWWA specification. The manufacturers' catalogues should also be consulted since they generally outline the class pressures routinely manufactured and contain design curves for pipe selection.

4.2.4 Steel Pipe

Par 1 Steel watermains should be manufactured in accordance with the latest version of the appropriate AWWA specifications. The AWWA specifications pertaining to steel pipe are:

- STEEL WATER PIPE 150 mm (6 in.) AND LARGER (formerly C201 and C202)-	AWWA C200
- COAL-TAR PROTECTIVE COATINGS AND LININGS FOR STEEL WATER PIPELINES - ENAMEL AND TAPE - HOT-APPLIED -	AWWA C203
- CHLORINATED RUBBER-ALKYD PAINT SYSTEM FOR THE EXTERIOR OF ABOVE GROUND STEEL WATER PIPING -	AWWA C204
- CEMENT-MORTAR PROTECTIVE LINING AND COATING FOR STEEL WATER PIPE -100 mm (4 in.) AND LARGER - SHOP APPLIED -	AWWA C205
- FIELD WELDING OF STEEL WATER PIPE -	AWWA C206
- STEEL PIPE FLANGES -	AWWA C207
- DIMENSIONS FOR STEEL WATER PIPE FITTINGS	AWWA C208

- COLD-APPLIED TAPE COATINGS FOR SPECIAL SECTIONS, CONNECTIONS, AND FITTINGS FOR STEEL WATER PIPELINES - AWWA C209
- CEMENT-MORTAR LINING OF WATER PIPE LINES - 100 mm (4 in.) AND LARGER - IN PLACE - AWWA C602

Par 2 For a detailed description of the design approach to be used for steel watermains, reference should be made to AWWA Manual M11 "Steel Pipe Design and Installation".

4.2.5 Thermoplastic Pipe

Par 1 The two most commonly used thermoplastics for watermains are polyvinyl chloride (PVC) and polyethylene (PE). Both materials are acceptable for use in the Province of Ontario. The Ministry of the Environment has prepared guidelines for water pipe made from PVC 1120 material. These can be found in Appendix D. PVC 1120 material is the only PVC pipe material accepted by the Ministry of the Environment for use in water distribution systems.

4.2.5.1 Polyvinyl Chloride (PVC)

Par 1 PVC pipe should be manufactured in accordance with the latest editions of either CSA B137.3 or AWWA C900. With pipe manufactured to the former specification, the maximum allowable internal pressure in

psi to which the pipe can be subjected (operating pressure + surge pressure) is designated by the Series number (Series 80, 100, 125, 160, and 200). With the latter specification, a Class rating system is used and the class number (100, 150 and 200) corresponds to the maximum allowable working pressure (operating pressure) in psi to which the pipe can be subjected. The class ratings provide for a pressure rise above the maximum working pressure caused by a surge that does not exceed that caused by an instantaneous velocity change of 0.6 m/s (2 fps).

Par 2 Both specifications rate the pipe at a working temperature of 23°C, or lower; if pipe is to be used at higher working temperatures, the effective pressure rating of the pipe must be reduced.

Par 3 For normal watermain trench conditions, the pipe strength requirements for PVC will be dictated by the expected internal pressures. External loadings will not decrease the ability of the pipe to withstand internal pressures until a deflection of 10 per cent of the diameter is reached. To avoid this weakening of the pipe, a maximum deflection limit of 5 per cent is suggested. For the methods to be used to calculate maximum deflection, reference should be made to Appendix D, "Guidelines for PVC 1120 Water Pipe".

Par 4 For municipal water supply systems, a minimum of series 160, or Class 100 PVC pipe (DR26 or DR25), is recommended by the Ministry of the Environment. For non-municipal type systems, series 80, 100 or 125 PVC pipe may be used if operating and/or transient pressures and external loading conditions permit.

4.2.5.2 Polyethylene (PE)

Par 1 Polyethylene pipe to be used for watermains in the Province of Ontario should be manufactured in accordance with either CSA B137.0 and B137.1 or *CGSB 41-GP-25. The CSA Standards cover pipe up to and including 150 mm (6 in.) diameter and the CGSB Standard covers nominal sizes from 90 mm (3.5 in.) to 1600 mm (48 in.).

Par 2 With PE pipe, the series number (45, 60, 80, 100, 125 and 160) represents the maximum allowable working pressure (operating pressure) in psi to which the pipe should be subjected, at a "working temperature" of 23°C (73.4°F), with an allowance for surge pressure of 3 times the series number. Transient (surge) pressures normally experienced with water distribution systems can be permitted to raise the total internal pressures above the pipe series rating provided that the normal operating pressure is below the series rating and

*Canadian Government Specification Board

the duration of the excessive pressure is short and followed by a recovery period of equivalent, or longer, duration than the excessive pressure.

Par 3 As with PVC, the effective pressure rating of PE pipe must be reduced if it is to be used at working temperates above 23°C. For instance, at temperatures between 30° and 38°C the pipe should not be operating in excess of 80 per cent of its series rating.

Par 4 PE pipe strength requirements for watermains will be dictated normally by the internal pressures. External loadings may become a factor if watermains are to be dewatered for long time periods, or where excessive live and/or trench loads are to be experienced. Manufacturer's design curves will generally provide sufficient information to allow a designer to select the required pipe series. It is recommended that long term deflections not be in excess of 5 per cent.

Par 5 For municipal water supply systems, a minimum of series 125 PE pipe is recommended by the Ministry of the Environment. For non-municipal type systems, Series 60, 80 or 100 may be used if internal pressure and external loading conditions permit.

4.3 PIPE BEDDING AND BACKFILLING

Par 1 The bedding and backfilling requirements for water-

mains vary greatly depending upon the type and class of watermain material used. Reference should be made to the previous sections on alternate pipe materials and the specifications quoted therein for specific bedding and backfilling requirements.

Par 2 In general, however, certain precautions should always be taken in pipe bedding. The trench bottom should be properly prepared to accept the watermain. It must be accurately graded so that the pipe may be evenly supported along its length. Special care should be taken at the joints to ensure that the weight of the pipe is not being supported by the joints alone. The trench bottom should be cleaned and free of stones and hard lumps and if this cannot be economically achieved, the trench should be over-excavated and backfilled with granular material. If bedrock is encountered, over excavation and granular cushioning should be carried out.

5.0 WATERMAIN APPURTENANCES

5.1 HYDRANTS

Par 1 All hydrants used on distribution systems in the Province of Ontario should be of the dry-barrel type to prevent freezing. They should be manufactured in accordance with AWWA C502-73.

Par 2 In areas where the water table will rise above the hydrant drain ports, the drain ports should be plugged and the barrels kept pumped dry to prevent freezing damage to the barrel and water system contamination. Where hydrant drains are not plugged, they shall drain to the ground surface, if topography permits, or to dry wells provided exclusively for that purpose. Under no circumstances should such drains be connected to storm or sanitary sewers.

Par 3 All fire hydrants should be provided with adequate blocking to prevent movement caused by thrust.

Par 4 For other hydrant requirements refer to Section 3.3 and consult with the municipal fire department.

5.2 VALVES AND VALVE CHAMBERS

Par 1 For the guidelines covering the placement of valves refer to Section 3.2. Also the Municipal Works Department should be consulted regarding their preferences with respect to valve locations at inter-

sections; line valve spacing; types of valves permitted; direction of rotation of wrench nut to open; maximum size of valve permitted in valve box; etc.

Par 2 Wherever possible, valves to be used in water distribution systems should be manufactured in accordance with recognized standards, such as those prepared by AWWA. The following AWWA standards cover valves used in water distribution systems:

- GATE VALVES - 75 mm (3 in.) through 1200 mm (48 in.) - AWWA C500
- RUBBER-SEATED BUTTERFLY VALVES - AWWA C504
- BALL VALVES - SHAFT OR TRUNION-MOUNTED - 150 mm (6 in.) through 1200 mm (48 in.) FOR WATER PRESSURES UP TO 2100 kPa (300 psi) - AWWA C507

Par 3 Valves 300 mm (12 in.) in diameter, or less, may have access provided to the operating nut via a valve box and stem assembly, but it is the recommendation of the Ministry of the Environment that all line valves larger than 300 mm (12 in.) in diameter be placed in valve chambers. Similarly, all air release valves and drain valves should also be located in chambers. To minimize the number of chambers required, consideration should be given to locating combinations of such appurtenances in a single chamber. These chambers and/or the discharge lines from air release, drain or blow-off valves should not

be connected directly to any storm or sanitary sewer. Instead, they should drain to the surface of the ground where they are not subject to flooding by surface water; to absorption pits underground; or, to a sump within the chamber, if the ground water level is above the chamber floor.

5.3 WATER SERVICES

Par 1 Water services must be at least 20 mm (3/4 in.) inside diameter and under the provisions of the Plumbing Code (Regulation 647) the following materials are acceptable. Municipal Works Departments should be consulted regarding local preferences.

a) Brass

b) Cast Iron

c) Copper

d) Ductile iron

e) Open hearth iron

f) Steel

g) Wrought iron

h) Polyethylene (rated working pressure 150 psi, or more)

i) Polyvinyl chloride (rated working pressure 150 psi, or more)

j) Asbestos cement

k) Polybutylene (CSA B137.7 and/or AWWA C902) for pipe up to 76 mm (3 in.)

Par 2 Reference should be made to the Plumbing Code for further discussion of the acceptable service pipe materials and the conditions under which they may be used.

Par 3 In selecting the diameter of a service connection, the designer should consider such factors as the following:

a) Peak water consumption of building serviced;

b) Total length of service which will be required to reach building;

c) Elevation of building;

d) Available head in watermain;

loss of head resulting from considerations a), b), c), fittings and meter; and required head at point of water usage.

Par 4 Recent studies have shown that for residential water services, the peak water demands can be as high as 1.1 L/s (15 gpm). Past practice has been to design for peak flow rates of 0.4 to 0.5 L/s (5 to 7 gpm). Head losses become excessive with 20 mm (3/4 in.) services for water flows much higher than 0.4 L/s (5 gpm). The use of 25 mm (1 in.) residential water services should, therefore, be considered, especially in the case of large homes, large lot sizes, etc.

Par 5 All water services should be equipped with a corp-

oration stop and a curb stop. The curb stop should be provided with a curb box.

5.4 THRUST BLOCKS

Par 1 Adequate restraint must be provided in water distribution systems to prevent pipe movement and subsequent joint failure. In the case of non-restraining mechanical and/or slip-on joints, this restraint should be provided by adequately sized thrust blocks positioned at all plugs, caps, tees, reducers, wyes, hydrants and bends deflecting $22\text{-}1/2^{o}$, or more. Depending upon internal pressures, pipe sizes and soil conditions, bends of lesser deflection may also require thrust blocking. An alternative approach that can be used to prevent joint failure is to either use pipe and jointing methods capable of resisting the forces involved (such as welded steel pipe, or polyethylene pipe with thermal butt-fusion joints) or use joint restraining methods, such as suitable metal tie rods, clamps or harnesses.

Par 2 In designing thrust blocks and other restraint systems, the designer should remember that transient pressures should be added to the normal operating pressures when calculating the thrust forces (if velocity of flow is very high, dynamic thrust should also be calculated); adequate corrosion protection must be provided for external clamps and

tie rods; the safe bearing values of soils should be reduced substantially from textbook figures if shallow trenches are used. For further discussion of thrust blocking and joint restraint design, reference should be made to the pipe manufacturer's catalogue, and other sources such as textbooks, watermain design manuals, etc.

APPENDIX A

Peaking Factors for Municipal[1] Water Supply Systems

POPULATION RANGE	MINIMUM RATE FACTOR[2] (MIN. HOUR)	MAXIMUM DAY FACTOR[3]	PEAK RATE FACTOR[4] (MAX. HOUR)
Up to 500	0.40	3.00	4.50
501 - 1000	0.40	2.75	4.13
1001 - 2000	0.45	2.50	3.75
2001 - 3000	0.45	2.25	3.38
3001 - 10000	0.50	2.00	3.00
10001 - 25000	0.60	1.90	2.85
25001 - 50000	0.65	1.80	2.70
50001 - 75000	0.65	1.75	2.62
75001 - 150000	0.70	1.65	2.48
Greater than 150000	0.80	1.50	2.25

Example: Assume a) Projected 20-year population of Town is 3,600 persons

b) Average per capita water consumption is 0.3 m^3/cap.d

Calculate a) Average day
b) Minimum rate
c) Maximum day
d) Peak rate

Solution a) Average day = 3600 x 0.3 = 1080 m^3/d
b) Minimum rate = 1080 x 0.5 = 540 m^3/d
c) Maximum day = 1080 x 2.00 = 2160 m^3/d
d) Peak rate = 1080 x 3.00 = 3240 m^3/d

Notes:

[1]These peaking factors are suitable for use with an entire municipal system with its variety of water uses (residential, industrial and commercial). For portions of a municipal system such as an industrial subdivision, they may over-estimate actual peaks and under-estimate minimum rates, whereas, with a purely residential area they may under-estimate the actual peaks and over-estimate the minimum rates. For sub-areas of a municipality refer to Section 2.1.1 for a discussion of peaking factors for residential, industrial and commercial areas.

[2]Minimum hourly consumptions may be estimated by multiplying the average day usage by the minimum rate factor. By definition, the minimum hour is the minimum usage rate on the maximum day.

[3]Maximum day usage may be estimated by multiplying the average day usage by the maximum day factor.

[4]Peak rate water usage may be estimated by multiplying the average day usage by the peak rate factor.

APPENDIX B

Application of MOE Guidelines on Provincially Funded Programs

Par 1 Where a conflict exists between the Ministry of the Environment's guideline and the minimum requirement of a Municipality which is receiving Provincial funding for capital works, the MOE guidelines shall be adhered to, except in cases where the Municipal standards have been found to be acceptable to MOE.

Par 2 Alternative materials as listed in Section 4.1 of the guidelines, shall be specified in the tender documents, and prices obtained for such alternatives, regardless of the eventual choice by the Municipality of the material finally used for construction.

Par 3 Direct Provincial grants to Municipalities will only be applicable to normal restoration associated with the construction of the proposed works and any reconstruction or rebuilding of roads, sidewalks, parking areas, etc. are not items which will be eligible for inclusion in the total cost of the project on which subsidy will be based.

APPENDIX C

Interim Policy and Guidelines to Govern Cross-Connections and Cross-Connection Controls

A. Policy to Govern Cross-Connections and Cross-Connection Control Devices

Par 1 No connection shall be made between a potable water system and a non-potable water system or any potential source of non-potable water or other contaminants. Should such a connection be unavoidable, an approved method of backflow prevention should be incorporated into the connection.

Par 2 Approved methods of backflow prevention include an atmospheric gap; a backflow preventer valve of the reduced pressure zone type or a vacuum breaker. Double checked valve type backflow preventers are not acceptable.

B. Guidelines Respecting Cross-Connection Control

Definitions

Par 1 Air gap - Means the unobstructed vertical distance through the free atmosphere between:

a) the lowest opening from any pipe or faucet supplying potable water to a tank or a fixture;

b) the flood level rim of the tank or fixture.

Par 2 Approved air gap - Shall be at least double the diameter of the supply pipe measured vertically

above the top rim of the vessel and in no case shall the air gap be less than 25 mm (1 in.).

Par 3 Approved backflow prevention device - Shall be a device that has been investigated and/or constructed and/or approved by any one of or to any one of or a combination of the following:

i) AWWA Standard for Backflow Prevention Devices - Reduced Pressure Zone Principal and Double Check Valve Types (AWWA C506-69);

ii) University of Southern California - Foundation for Cross-Connection Control Research;

iii) Canadian Standards Association.

Par 4 Backflow - Means such flow of:

a) water from any place; or

b) any solid, liquid or gaseous substance or any combination thereof,

into a potable water system as may make the water in that system non-potable.

Par 5 Backflow preventer - Means a device to prevent backflow from the outlet end of the potable water system.

Par 6 Backflow prevention device - Means any effective device, method, or construction used to prevent backflow into a potable water system.

Par 7 Back siphonage - Shall mean a form of backflow due to negative or sub-atmospheric pressure within a

potable water system.

Par 8 Cross-connection - Means any connection or structural arrangement between a potable water supply system and any non-potable source or system through which backflow can occur. By-pass arrangements, jumper connections, removable sections, swivel or change-over devices, and other temporary or permanent devices through which, or because of which, backflow can occur, are considered cross-connections.

Par 9 Cross-connections - May be regarded as direct or indirect. A direct connection is an arrangement whereby a potable water system is physically connected to a system containing non-potable water, sewage or other hazardous liquids, etc. An indirect connection is an arrangement whereby non-potable water in a system may be blown, sucked or otherwise diverted into a potable water system.

Par 10 Double check valve type backflow preventer - Consists of an assembly of independently acting check valves located between two tightly closing shut-off valves but without a pressure differential relief valve.

Par 11 Flood level rim - Means the top edge of a receptacle from which water overflows.

Par 12 Interconnection - Is any piping arrangement whereby the potable water supply system is interconnected with a non-potable water supply which would be capable of imparting contamination or toxic materials to the potable water system.

Par 13 Non-pressure type vacuum breaker - Is a type of device which is better known as an atmospheric vacuum breaker; and is always placed downstream from a shut-off valve; and, which will cause its air vent to close when the water flows in the normal direction; but, as soon as the water ceases to flow, the air vent valve is caused to open, thus interrupting the possible back siphonage affect.

Par 14 Potable water - Means water fit for human consumption.

Par 15 Potable water system - Means all sources, facilities, and appurtenances between the source and point of delivery, such as valves, pumps, pipes, conduits, tanks, receptacles, fixtures, equipment and appurtenances used to produce, convey, treat or store a potable water for public consumption or use.

Par 16 Pressure type vacuum breaker - Is a type of device which is designed to close with aid of a spring when the line pressure drops and at the same time to open to the atmosphere so that no non-potable liquids can be siphoned back into the potable water system.

Being spring loaded, it does not rely upon gravity as does the non-pressure type vacuum breaker. This type of device should not be installed where it might be subjected to any back pressure condition.

Par 17 Reduced pressure principle device - Is an assembly of two internally loaded, specially designed independently operating check valves with an automatically operated pressure differential relief valve between the checks specifically designed to maintain a zone of reduced pressure between the two check valves at all times.

Application

Par 18 Sewage Works Facilities - In general, no connection should be made between a sewerage works facility and a potable water system. Where such a connection is deemed necessary for the purpose of providing diesel cooling water, pump seal water, washroom facilities or other process requirements, the service connection between the sewage works and the potable water system should be equipped with an approved backflow preventer device.

Par 19 In addition, it is recommended that backflow preventor devices be installed on all potentially hazardous connections such as yard hydrants, lab sinks, chemical mixing tanks, etc. within the sewage works facilities such as to minimize the

potential for contamination of the internal plumbing to the sewage works facilities.

Par 20 Water Works - Any connection between the potable water system within a water works facility (treatment plant) and a potential source of non-potable water (i.e. pump seal units, diesel generator cooling systems, chemical mixing facilities, laboratory facilities, backwash facilities) should be equipped with an approved backflow preventer device.

Par 21 In addition, any non-potable piping (i.e. backwash water piping, sanitary piping, etc.), which passes through or in the vicinity of potable water storage facilities should be concrete encased. Under no circumstances should piping or conduits designed for the purpose of conveyance of non-potable substances within a water treatment plant actually pass through the potable water reservoir (i.e. be submerged).

Par 22 The overflow and drain facilities from potable water storage should not be connected to sewage works facilities but should terminate with an atmospheric gap.

Par 23 Industrial - In general, any potentially hazardous industrial connection to a potable water system should be equipped with an approved backflow pre-

vention device.

<u>Additional References</u>

a) Cross-Connection Control Manual - U.S. Environmental Protection Agency/Water Supply Division.

b) AWWA M14 - Backflow Prevention Manual.

c) University of Southern California/School of Engineering/Foundation for Cross-Connection Control Research-Manual of Cross-Connection Control-Recommended Practice.

Proposed Policy for Location of Sewers and Watermains

1. Sewers and watermains located parallel to each other should be constructed in separate trenches maintaining the maximum practical horizontal separation.

2. In cases where it is not practical to maintain separate trenches or the recommended horizontal separation cannot be achieved, the Ministry of the Environment may allow deviation from the above.

Guidelines

1. GENERAL

Par 1 Ground or surface water may enter an opening in the water distribution system with the occurrence of a negative internal/positive external pressure condition. Ground water may enter the distribution system at leaks or breaks in piping, vacuum-air relief valves, blow-offs, fire hydrants, meter sets, outlets, etc. Water pressure in a part of the system may be reduced to a potentially hazardous level due to shut downs in the system, main breaks, heavy fire demand, high water usage, pumping, storage, or transmission deficiency.

Par 2 The relative location of sewers and watermains (including appurtenances) and types of material used for each system are important considerations in designing a system to minimize the possibility of contaminants entering the water distribution system.

Par 3 The use of, and adherance to, good engineering and construction practice will reduce the potential for health hazard in the event of the occurrence of conditions conducive to ground water flow into the water distribution system.

2. PARALLEL INSTALLATIONS

Par 1 1. Under normal conditions, watermains should be laid with at least 2.5 metres horizontal separation from any sewer or sewer manhole; the distance shall be measured from the nearest edges.

a) Under unusual conditions, where a significant portion of the construction will be in rock, or where it is anticipated that severe dewatering problems will occur or where congestion with other utilities will prevent a clear horizontal separation of 2.5 metres, a watermain may be laid closer to a sewer, provided that the elevation of the crown of the sewer is at least 0.5 metres below the invert of the watermain. Such separation shall be of in-situ material or compacted backfill.

b) Where this vertical separation cannot be obtained, the sewer shall be constructed of materials and with joints that are equivalent to watermain standards of construction and shall be pressure tested to assure water tightness.

c) In rock trenches, facilities should be provided to permit drainage of the trench to minimize the effects of impounding of surface water and/or leakage from sewers in the trench.

3. CROSSINGS

Par 1 1. Under normal conditions, watermains shall cross above sewers with sufficient vertical separation to allow for proper bedding and structural support of the watermain and sewer main.

Par 2 2. When it is not possible for the watermain to cross above the sewer, the watermain passing under a sewer shall be protected by providing:

a) A vertical separation of at least 0.5 metres between the invert of the sewer and the crown of the watermain.

b) Adequate structural support for the sewers to prevent excessive deflection of joints and settling.

c) That the length of water pipe shall be centred at the point of crossing so that the joints will be equidistant and as far as possible from the sewer.

4. SERVICE CONNECTIONS

Par 1 Wherever possible, the construction practices outlined in this guideline should apply with respect to sewer and water services.

5. TUNNEL CONSTRUCTION

Par 1 If the "Tunnel" is of sufficient size to permit a

man to enter the tunnel for the purposes of maintenance, etc., it is permissible to place the sewer and watermain through the tunnel providing the watermain is hung above the sewer.

Par 2 If the tunnel is sized only to carry the pipes, or if the tunnel is subject to flooding, the sewer shall be constructed of materials and with joints that are equivalent to watermain standards of construction and shall be pressure tested to assure water tightness.

6. <u>DESIGN FACTORS</u>

Par 1 When local conditions do not permit the desired spacing, or water and sewer lines or other conditions indicate that detailed investigations are warranted, the following factors should be considered in the design of the environment and relative location of water and sewer lines.

Par 2 This list of factors should be considered as a guide and not all inclusive.

a) Materials, types of joints and identification for water and sewage pipes;

b) Soil conditions, e.g. in-situ soil and backfilling materials and compaction techniques;

c) Service and branch connections into the watermain and sewer lines;

d) Compensating variations in the horizontal and vertical separations;

e) Space for repair and alterations of water and sewer pipes;

f) Off-setting of pipes around manholes;

g) Location of ground-water table and trench drainage techniques;

h) Other sanitary facilities such as septic tanks and tile fields, etc.

7. VALVE, AIR RELIEF, METER AND BLOW-OFF CHAMBERS

Par 1 a) Chambers or pits containing valves, blow-offs, meters or other such appurtenances to a water distribution system shall not be connected directly to any storm or sanitary sewer, nor shall blow-offs or air-relief valves be connected directly to any sewer.

b) Such chambers or pits shall be drained to the surface of the ground where they are not subject to flooding by surface water; to absorption pits underground or to a sump within the chamber where ground water level is above the chamber floor.

8. RESERVOIRS BELOW NORMAL GROUND SURFACE

Par 1 Sewers, drains, and similar sources of contamination should be kept at least 15 m (50 ft.) from the reservoir. Mechanical-jointed water pipes, pressure

tested in place to 350 kPa (50 psi) without leakage, may be used for gravity sewers at lesser separations.

9. UNACCEPTABLE INSTALLATIONS

Par 1 No watermain or service line shall pass through or come into contact with any part of a sewer or sewer manhole.

APPENDIX D

Policy to Govern the Use of PVC 1120 Pipe for Pressure Applications

1. The Ministry will allow the use of PVC 1120 pipe for watermains.

2. Such pipe shall be certified as conforming to CSA Standard B137.3 unless specifically excepted.

MINISTRY OF THE ENVIRONMENT

GUIDELINES FOR PVC 1120 PRESSURE PIPE

1. GENERAL REQUIREMENTS

1.1 PIPE SELECTION AND INSTALLATION

Par 1 The use of PVC 1120 pipe for water-system applications shall conform with the following requirements:

1) Working Pressure - The working pressure of the water system, as defined in Section 2.1, shall not exceed the pressure class of pipe used as calculated according to Section 3.1.
2) Total System-Pressure - The Total System-pressure, as defined in Section 2.1, shall not exceed a corresponding pressure rating for the pipe used that is determined in accordance with Section 3.2.
3) Installation - Pipe shall be installed underground in a manner that will assure that external loads will not subsequently cause a decrease of more than 5 per cent in its vertical cross-section dimension.

1.2 INTERNAL PRESSURES AND EXTERNAL LOADS

Par 1 The design of pipe for internal pressures and external loads shall conform with the methods described herein.

2. DESIGN TERMINOLOGY

2.1 DEFINITIONS

Par 1 Under this guideline, the following definitions shall apply:

2.1.1 Working Pressure - The maximum anticipated sustained operating pressure of the water system.

2.1.2 Surge Pressure - The maximum pressure increase above working pressure, sometimes called water hammer, that is anticipated in the system as a result of change in the velocity of the water column when valves are operated, or pumps are started or stopped.

2.1.3 Total System-Pressure - The sum of the working pressure plus the surge pressure.

2.1.4 Hydrostatic Design Basis - The long-term, hydrostatic-strength (hoop stress) rating in psi of a specific plastic-pipe material for water service at a particular maximum operating-temperature; as determined by hydrostatic tests and detailed evaluation procedures in accordance with ASTM D2837, a Method of Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials.

2.1.5 Factor of Safety - A number used to reduce the hydrostatic design basis of a pipe material and thus establish an allowable design stress for that material (Section 3.6).

3. INTERNAL PRESSURES

3.1 PRESSURE CLASS - PIPE

Par 1 The pressure class (working-pressure rating) of PVC 1120 pipe shall be determined by using one of the following formulas:

$$PC = \left(\frac{2t}{D-t} \times \frac{HDB}{F}\right) - P_s; \text{ or} \qquad (1)$$

$$PC = \left(\frac{2}{P-1} \times \frac{HDB}{F}\right) - P_s \qquad (2)$$

Where PC = Pressure class, k Pa

t = Minimum wall-thickness, mm

D = Average outside-diameter, mm

HDB = Hydrostatic design basis, K Pa

F = 2.0 factor of safety (Sec. 3.6)

P_s = Allowance for surge, pressure K Pa (Sec. 3.3.1)

R = Dimension ratio

3.2 TOTAL PRESSURE-PIPE

Par 1 The pressure rating of PVC 1120 pipe for total system-pressure shall be determined by using one of

the following formulas:

$$P = \frac{2t}{D-t} \times \frac{HDB}{F} \text{ ; or} \qquad (3)$$

$$P = \frac{2}{R-1} \times \frac{HDB}{F} \qquad (4)$$

Where P = Pressure rating for total system-pressure, kPa; and other factors are the same as in Formulas 1 and 2

3.3 SURGE PRESSURE

Par 1 3.3.1 Surge-Pressure Allowances - An allowance for surge pressure equal to not less than that generated by an instantaneous velocity change of 0.6 m/s shall be made in all cases. Excessive surge pressures should be prevented by elimination of the causative condition or providing automatic surge-pressure relief.

Par 2 3.3.2 Pressure Rise - The wave velocity and pressure rise resulting from abrupt change in the velocity of a column of water shall be determined using the following formulas:

$$a = \frac{1420}{(1+KD_i/Et)^{\frac{1}{2}}} \qquad (5)$$

where a = Wave velocity, m/s

K = Bulk modulus of water = 2000 MPa

D_i = Inside diameter of pipe, mm

E = Modulus of Elasticity of pipe material (for PVC 1120, 2800 MPa)

T = Wall thickness of pipe, mm

$$\frac{KD_i}{Et} = \frac{K\ (R-2)}{E}$$

where R = Dimension ratio of pipe = D_o/t

D_o = Outside diameter of pipe, mm

$$Ps = \frac{9.79\ aV}{g}$$

where P_s = Pressure rise, kPa

a = Wave velocity, m/s

V = Velocity change, m/s, occurring within the critical time 2 L/a where L is the length of the pipeline in metres

g = Gravitational acceleration = 9.81 m/s^2

3.4 HYDROSTATIC DESIGN BASIS (HDB)

Par 1 The HDB of PVC 1120 pipe (Class 12454-A and B materials) for water service at 23°C is 28 MPa. The HDB will be less than 28 MPa for pipe use at temperatures above 23°C (Sec. 3.5).

3.5 DESIGN STRESS

Par 1 The allowable design stress (HDB/F) for use of PVC 1120 pipe at 23°C and lower temperatures is 14 MPa. For pipe use at higher operating-temperatures, the allowable design stress shall be determined by use of an HDB rating recommended by the

Plastics Pipe Institute for the operating temperature or by applying the appropriate temperature coefficient given in Table 3, Section 7.4, to the design stress allowed for pipe service at 23°C. The temperature coefficients are de-rating factors that may be applied also to pressure-class ratings for pipe used at temperatures above 23°C.

3.6 FACTOR OF SAFETY

Par 1 The 2.0 factor of safety specified for use in the pressure-class and total-pressure formulas is only a portion of that provided for working pressure and for total system-pressure.

Par 2 There are two pressure conditions of concern and a different factor of safety applies to each. These conditions are:

1) sustained working pressure which is a long-term hydrostatic strength (HDB) of the pipe, and
2) total system-pressure which is a short-term peak pressure condition and which relates to the short-term hydrostatic strengths of the pipe. The long-term and short-term hydrostatic strengths of PVC 1120 pipe at 23 C are respectively 14 and 44 MPa.

Par 3 A factor of safety is provided for total system-pressure. It is the ratio of 44 MPa (minimum short-term strength) to 14 MPa (allowable design-stress, HDB/2.0).

4. EXTERNAL LOADS

4.1 DEAD LOADS

Par 1 The earth load shall be determined using the Modified Iowa State Formula (1) for loads imparted to a flexible pipe, as follows:

$$W_e = C_d w \, B_d B_c \qquad (7)$$

where W_e = Earth load, N/lin. metre

C_d = A coefficient, based on type of backfill soil and on the ratio of H (depth of fill to top of pipe, m) to B_d. (See Figure 1)

w = Unit of weight of soil, N/m^3

B_d = Ditch width at top of pipe, m

B_c = Outside diameter of pipe, m

4.2 LIVE LOADS

Par 1 The live load (W_l) shall be determined using the modified AASHO H20 loading as given in Table 1, which is based on two passing trucks with adjacent wheels 3 feet apart, having a 40 320 N load on unpaved road or flexible pavement, and which includes 50 per cent impact.

TABLE 1

Highway Live Loads[a]

Pipe Size in.	2.5	3.5	Depth of Cover, ft. 5	8	12	16	20	24
4	297	162	81	54	40	27	18	14
6	567	324	189	94	68	40	26	20
8	783	486	297	148	94	54	36	28
10	972	621	378	189	108	68	45	35
12	1161	756	459	243	122	81	53	41

[a]This table has not been converted to the S.I. system as it has been extracted from the non-metricated Table 1-8, ANSI A21.1 (AWWA C101).

4.3 TOTAL LOAD

Par 1 The total load (W) on buried flexible pipe is as follows:

$$W = W_e + W_1, \text{ N/lin. metre} \qquad (8)$$

5. DEFLECTION

5.1 GENERAL

Par 1 The stresses that result from internal pressure and external load are not additive in the design of a flexible conduit such as PVC pipe. Although a maximum deflection of 5 per cent is specified in

1.1.3, PVC pipe can be deflected up to 10 per cent without reducing its ability to resist internal pressure. Failure modes are discussed in Section 7.

5.2 DESIGN THEORY - EARTH LOADS

Par 1 The best documented and best known design theory for the deflection of a cylindrical horizontal tube under earth load is Spangler's (2,3) Modified Formula for the deflection of a buried unpressurized tube. The formula for PVC pipe is as follows:

$$Y_v = \frac{D_e\ KW_e}{2E/3(R-1)^3 + 0.061E'} \qquad (9)$$

Where Y_v = Vertical deflection of pipe, m

D_e = Deflection lag factor (for plastic, 1.5)

K = Bedding constant (See Table 2, Sec. 5.4)

W_e = Earth load on pipe (N/lin metre)

R = Dimension ratio

E = Modulus of Elasticity of pipe material (for PVC 1120, 2.76×10^9 Pa)

E' = Modulus of Soil Reaction (See Table 2)

5.3 EARTH LOAD PLUS LIVE LOAD

Par 1 For inclusion of live loads, Spangler's Formula must be further modified since the deflection lag factor is not applicable to live loads. The formula is as follows:

$$Y_v = \frac{D_e KW_e + KW_1}{2E/3(R-1)^3 + 0.061E'} \qquad (10)$$

where W_1 = Live load on pipe (N/lin metre) and other factors are the same as in Formula 9.

5.4 DEFLECTION FORMULA FACTORS - D_e, K and E'

Par 1 The values for D_e, K and E' corresponding to different pipe-embedment conditions for use in Formulas 9 and 10 are given below in Table 2.

TABLE 2

Embedment Class[a]	D_e	Bedding Angle	K	E',Pa
Class B	1.50	120^o	0.090	$4.8x10^6$ [b]
Class C	1.50	60^o	0.102	$2.8x10^6$ [b]
Class D	1.50	0^o	0.110	$1.0x10^6$ [b]

[a]As described in ASCE Manual No. 37 (WPCF Manual No. 9)(6).

Note: Granular bedding material, as defined in these manuals, is specified for Embedment Classes B and C.

[b]If the sidefill material is compacted to 85 per cent Standard Proctor Density, the value of E' can be raised to 6.9×10^6 for Class B and to 4.8×10^6 for Class C.

6. INSTALLATION

6.1 PIPE EMBEDMENT

Par 1 The embedment of pipe shall conform with Class B,

C or D, as detailed in ASCE Manual No. 37(6); or with the recommended practices given in ASTM D2321 (7). A flexible pipe, unlike a rigid pipe, tends to bed itself. For flexible pipe, the most important parameters are stability of the bedding and density of the sidefills. Installation precautions are given also in ASTM D2321(7).

7. FAILURE MODES

7.1 GENERAL

Par 1 Flexible conduits can fail by buckling or collapse due to excessive external load, a negative or vacuum pressure, excessive bending stresses in the walls, excessive deflection, or a combination of these forces. Plastic conduits can also fail by reduction of ring stiffness (strength) due to excessive temperature of the fluid being transported or of the environment in which they are installed.

7.2 BUCKLING

Par 1 Experiments at the Utah State University now being conducted by Dr. Reynold Watkins (unpublished to date) indicate that plastic pipe does not fail by buckling in the same mode as steel pipe. Steel pipe dimples in, the dimple reverses curvature, and then folds in on the lower portion. Steel follows Timoshenki's formula in AWWA M11(4) in a free environment, but the formula must be modified if

the pipe is confined in an earth envelope. Plastic pipe, however, tends to deform (flatten) during vertical deflection and then fold in upon the lower portion. Therefore, if deflection is controlled, buckling will not occur under normal embedment conditions.

7.3 NEGATIVE OR VACUUM PRESSURE

Par 1 According to Dr. Watkin's experiments, negative or vacuum pressures cannot collapse an underground plastic pipe that is properly encased in a soil envelope and exposed to normal service temperatures. However, if the temperature of a plastic pipe is excessive due to temperature of fluids conveyed or exposure to sunlight, application of a negative pressure can cause pipe collapse.

7.4 EXCESSIVE TEMPERATURE

Par 1 If PVC pipe is used to convey fluids of excessive temperature or is installed in an environment where excessive temperatures can influence the conduit, the the allowable design stress should be appropriately reduced according to the following Table 3: or for operating temperatures that do not exceed 90°F, pipe of a pressure class next higher to that required for service at 73°F may be used.

TABLE 3

TEMPERATURE COEFFICIENTS

Maximum Service Temperature F	C	Per cent of the Allowable Design Stress or Pressure Class Rating at 73°F
80	27	88
90	32	75
100	38	62
110	43	50
120	49	40
130	54	30
140	60	22

7.5 BENDING STRESSES IN WALLS

Par 1 Plastic pipe embedded in soil acts similar to steel pipe and tends to bed itself and thereby re-adjusting wall stresses. The pipe will not fail from excessive wall stresses if deflection is controlled by proper installation.

8.1 PIPE DIMENSIONS

Par 1 Pipe manufactured to Cast Iron Pipe Size dimensions will be considered an acceptable alternative if it meets the requirements of CSA Standard B137.3 in all other respects.

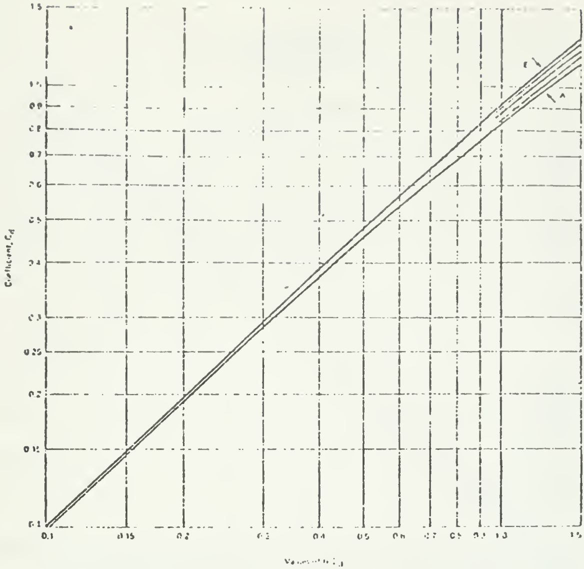


Fig. A.1a Computation Diagram for Earth Loads on Trench Conduits (Conduits Buried in Trenches)

$A = C_d$ for $K\mu$ and $K\mu' = 0.1924$ for granular materials without cohesion
$B = C_d$ for $K\mu$ and $K\mu' = 0.165$ maximum for sand and gravel
$C = C_d$ for $K\mu$ and $K\mu' = 0.150$ maximum for saturated topsoil
$D = C_d$ for $K\mu$ and $K\mu' = 0.130$ ordinary maximum for clay
$E = C_d$ for $K\mu$ and $K\mu' = 0.110$ maximum for saturated clay

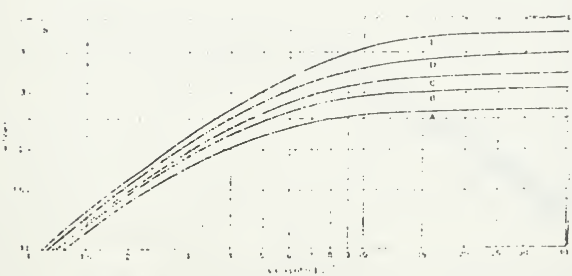


Fig. A.1b Expanded Scale of Computation Diagram for Earth Loads on Trench Conduits

PVC PRESSURE PIPE

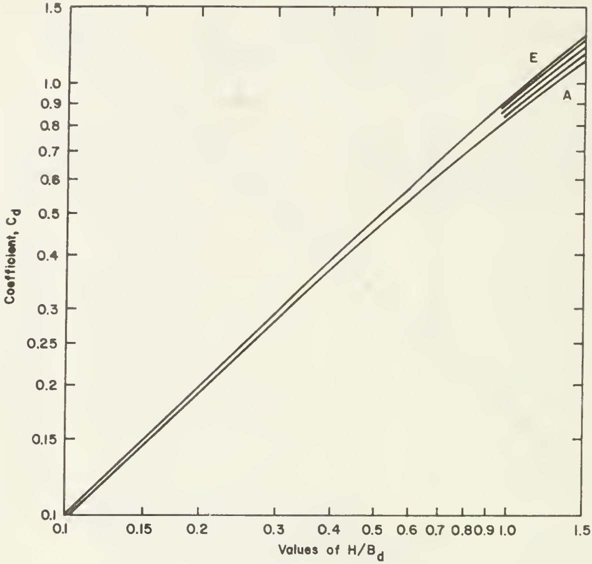


FIG. A.1a COMPUTATION DIAGRAM FOR EARTH LOADS ON TRENCH CONDUITS (CONDUITS BURIED IN TRENCHES)

A = C_d FOR $K\mu$ AND $K\mu'$ = 0.1924 FOR GRANULAR MATERIALS WITHOUT COHESION

B = C_d FOR $K\mu$ AND $K\mu'$ = 0.165 MAXIMUM FOR SAND AND GRAVEL

C = C_d FOR $K\mu$ AND $K\mu'$ = 0.150 MAXIMUM FOR SATURATED TOPSOIL

D = C_d FOR $K\mu$ AND $K\mu'$ = 0.130 ORDINARY MAXIMUM FOR CLAY

E = C_d FOR $K\mu$ AND $K\mu'$ = 0.110 MAXIMUM FOR SATURATED CLAY

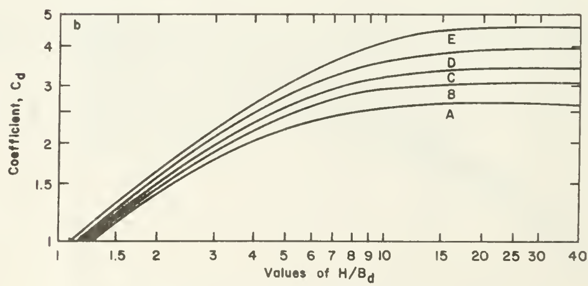


FIG. A1b EXPANDED SCALE OF COMPUTATION DIAGRAM FOR EARTH LOADS ON TRENCH CONDUITS

APPENDIX E

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